

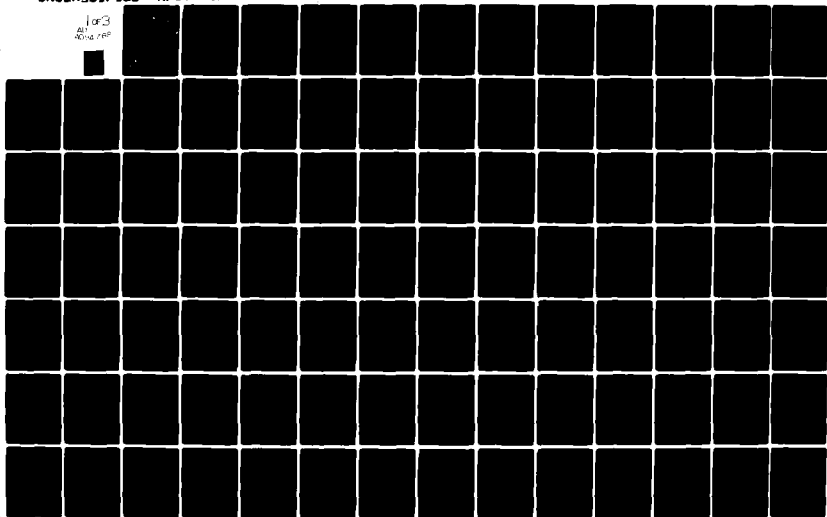
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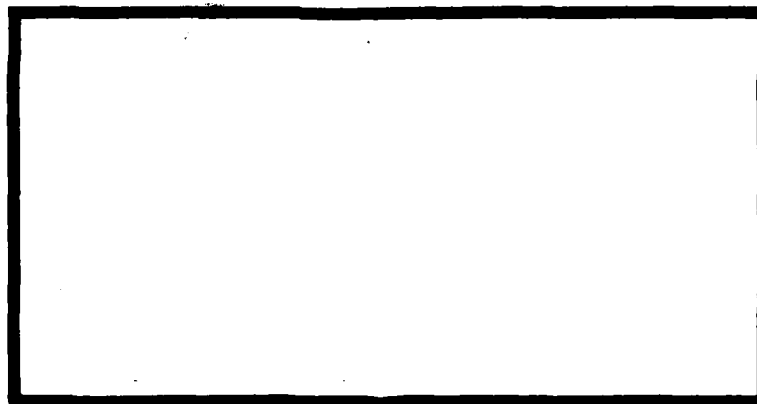
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A SYSTEM DYNAMICS MODEL FOR
ASSESSING THE COST-EFFECTIVENESS OF
USAF ENGINEERING OFFICER
COMPENSATION POLICIES.

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THESIS

AFIT/GOR/OS/80D-7/ Kenneth L. Williams
Captain USAF

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A SYSTEM DYNAMICS MODEL FOR ASSESSING THE
COST-EFFECTIVENESS OF USAF ENGINEERING
OFFICER COMPENSATION POLICIES

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

Kenneth L. Williams, B.S., M.S.
Capt USAF

Graduate Operations Research

December 1980

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Preface

One of the principal concerns expressed by the Air Force leadership today is that we have too few engineering officers. This report discusses this shortage and presents a methodology for evaluating alternative policy proposals to alleviate the shortfall. The research was conducted with three audiences in mind: (1) decision makers who determine policies effecting the retention of Air Force engineering officers, (2) staff members and analysts involved in formulating such policies, and (3) my thesis committee. (It is, after all, primarily a scholastic exercise; it certainly proved to be a learning experience.)

The body of this thesis was written with the decision maker in mind. With the exception of Chapter III, every attempt was made to include only those discussions directly supporting the results of the study. This approach assumes that decision makers will either trust my work or, more appropriately, ask their staff to assess the level of confidence one should place in the methodology by evaluating the details documented in Chapter III, pages 55 through 116, and in the Appendices. Appendices A and D assume an understanding of multivariate analysis techniques. And, although the terminology is explained, some knowledge of System

Dynamics and the DYNAMO computer programming language would be helpful in understanding Chapter III.

Although I received tremendous cooperation from many people in the Air Force Manpower and Personnel Center, the Aeronautical Systems Division of Air Force Systems Command, and the Air Force Institute of Technology, this document has not been coordinated with any Air Force agency. As such, the opinions, conclusions, and errors in the report can only be interpreted as my own. I cannot, however, claim full credit for the report. I am sincerely indebted to many individuals, a few of which are mentioned below.

Lieutenant Colonel Thomas D. Clark, Jr., M.A., M.B.A., D.B.A., served as my thesis advisor. His penetrating insight and exceptional expertise in identifying problems contributed substantially to this effort. Dr. Robert F. Allen, A.B., M.A., Ph.D., and Lieutenant Colonel Charles W. McNichols III, B.S., M.S., Ph.D., provided many helpful comments on previous drafts of this report. Captain Aaron R. DeWispelare, B.S., M.S., advised me on the multi-attribute ability theory techniques employed in Appendix D. It should be noted that the guidance I received from these distinguished professors was better than the report may reflect.

Lieutenant Colonel Hugo Weichel devoted many hours from a tight schedule to fill the decision maker role in establishing the measure of effectiveness developed for this study. A special word of appreciation is due to

Mrs. Phyllis Reynolds who worked late nights and weekends to type this report on time after I missed my deadlines.

Finally, and most importantly, Mrs. Judy Williams, my wife, helped in many ways from editing to providing badly needed moral support.

I would welcome any comments readers may have concerning any aspect of this report. I would also be glad to furnish a card deck of the DYNAMO computer program developed in this study and advise on how to use it. Such comments or requests may be addressed to:

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Table of Contents

	Page
Preface	ii
List of Figures	vii
List of Tables	x
Abstract	xii
I. Introduction	1
Purpose of This Thesis	7
Objectives of the Study	8
Is There Really a Shortage of Engineers?	9
The "Manning Less Than Authorized" Shortage . .	9
The "Compared to Russia" Shortage	12
The "Supply versus Demand" Shortage	14
Summary	21
What Can be Done About the Shortage?	21
Approach of the Study	25
Overview of the Report	31
II. Incentives	33
Literature Review	33
Analysis of the Air Force Quality of Life Survey	38
III. The System Dynamics Model	50
Abstract of the Development Engineering Officer Personnel System	51
Viewpoint for Evaluating the Model's Design . .	53
Section 1: Manpower Levels	55
Verbal Description	55
Flow Diagrams	58
Dynamo Equations	60
Mathematical Model	62

	Page
Section 2: Productive Capacity	66
Section 3: Voluntary Separation Rates	69
Causal Loop Diagrams	73
Section 4: Military Pay	77
Section 5: Civilian Pay	87
Section 6: Accession Rates	94
Section 7: Promotion Structure	100
Section 8: Separations Due to Passovers	108
Section 9: Transfers	110
Section 10: Cumulative Cost Calculations	111
Voluntary Separation Costs	115
Accession Costs	116
Vested Retirement Costs	116
Forced Separation Costs	116
Preliminary Model Test Runs	117
Summary	129
IV. Summary and Recommendations	131
Incentives	131
Productive Capacity	133
System Dynamics Model	137
Conclusion	139
Bibliography	141
Appendix A: Compendium of Relevant Studies	148
Appendix B: Model Flow Diagram and Equations	166
Appendix C: Demographic Data for Development Engineer Officer Responses to the Air Force Quality of Life Survey	187
Appendix D: Productive Capacity Function	188
Vita	219

List of Figures

Figure		Page
1.	Comparison of Non-government Engineers' Salary Increases to Other Occupations	16
2.	Comparison of Civilian Engineering Median Salaries With Military Pay	19
3.	Conceptualization of Engineering Capacity Provision Process	22
4.	Model Conceptualization	28
5.	Presentation of Typical QOAFI Question	40
6.	Comparison of Mean Quality of Air Force Life Factor Satisfaction Levels	41
7.	Partial Flow Diagram	59
8.	Sequence of Computation	61
9.	Model Structure Representing Manpower Levels .	63
10.	Model Structure Representing Productive Capacity	67
11.	Model Structure Representing Voluntary Separations	70
12.	Hypothesized Determinants of Voluntary Separation Rates Causal Loop Diagram	73
13.	Hypothesized Relationship Between the Indexed Ratio of Military to Civilian Pay and the Voluntary Separation Rate Factor .	75
14.	Hypothesized Determinants of Military Pay Causal Loop Diagram	77
15.	Model Structure Representing Military Pay . .	78
16.	Annual Inflation Rates 1950-1977	85
17.	One Series of Inflation Rates Randomly Generated by the Model	86

Figure		Page
18.	Model Structure Representing Civilian Engineer Pay	88
19.	Engineer Salary Increases Relative to Other Occupations Related to the Deutsch, Shea, and Evans, High Technology Recruitment Index	91
20.	Deutsch, Shea and Evans, Inc. High Technology Recruitment Index	92
21.	Sample Projection of Demand for Engineers . . .	93
22.	Hypothesized Determinants of Accessions Causal Loop Diagram	95
23.	Model Structure Representing Accessions . . .	97
24.	Model Structure Representing Promotions . . .	102
25.	Test of Promotion Structure	107
26.	Model Structure Representing Passovers	109
27.	Model Structure Representing Transfers	111
28.	Model Structure for Estimating Costs	112
29.	Manning Projections with Current Compensation Policies	119
30.	Productive Capacity Projection with Current Compensation Policies	120
31.	Manning Projections Assuming Accession Bonus	122
32.	Productive Capacity Projection Assuming Accession Bonus	123
33.	Manning Projection with Increased Compensation for all Company Grade Officers and a Cost Constraint on Accessions	125
34.	Productive Capacity Projection with Increased Compensation for all Company Grade Officers and a Cost Constraint on Accessions	126

Figure		Page
35.	Manning Projections Assuming Accession Bonus, and Increasing Civilian Demand for Engineers	127
36.	Productive Capacity Projection Assuming Accession Bonus and Increasing Demand for Engineers	128
37.	Hypotheses Underlying the Model Causal Loop Diagram	138
D-1.	Field Grade Officer vs. Captain Tradeoffs With Low Lieutenant Manning	196
D-2.	Field Grade Officers vs. Captain Tradeoffs With High Lieutenant Manning	198
D-3.	Check for Weak Difference Independence	200
D-4.	Sample of Ad Hoc Productive Capacity Calculations	201
D-5.	General Relationship Between Assigned 28XX Officers and Production	203
D-6.	Decision Maker's View of Increase of Average Productivity with Experience	210
D-7.	Productive Capacity of Lieutenants with Captains and Field Grade Officers Held Constant	214
D-8.	Productive Capacity of Captains with Lieutenants and Field Grade Officers Held Constant	214
D-9.	Productive Capacity of Field Grade Officers with Lieutenants and Captains Held Constant	215

List of Tables

Table		Page
I.	Military Manning Projections for Officers in Career Fields 26XX, 27XX, 305X, and 55XX	2
II.	Officer Retention: Engineer Rates Compared to All Support Officers	2
III.	Air Force Total Engineering Authorizations/ Manning	3
IV.	Development Engineer Officer Manning by Grade	5
V.	Rank Ordering of Factors Bearing on Career Intent	37
VI.	Comparison of Career Intent Survey Responses .	39
VII.	Comparison of Primary Negative Career Decision Factors	44
VIII.	Comparison of Primary Affirmative Career Decision Factors	45
IX.	Comparison of Responses on Military Pay . . .	46
X.	Attrition Elasticities for Initial Runs . . .	77
XI.	Promotion Opportunities (PO) and Required Times in Grade (TIG)	101
A-I.	Importance and Possibility Ratings and Relationships Survey of Former AFIT Students - Sample of Scientific Officers (AFSCs 2XXX)	150
A-II.	Mean Values of Satisfaction and Importance Ratings of Job Characteristics, and Their Relationship - Air Proving Ground Center Survey - Scientific/Engineering Officer (AFSC 25XX-57XX)	152

Table		Page
A-III.	Sub-sample Regression/Correlation Values of Career Intent with Air Force Instrumentality/Valence Products (28XX Sample)	157
A-IV.	Descriptive Statistics for Expectancy Terms	158
A-V.	Ten Most Important Job Features	160
A-VI.	Ten Least Important Job Features	160
A-VII.	Standardized Regression Coefficients from Multiple Regressions With and Without the Correlates	163
C-I.	Grade Distribution of 28XX Respondents . . .	187
C-II.	Distribution by Command of 28XX Respondents.	187
D-I.	Hypothetical Organization for Checking Independence Conditions	195
D-II.	Subjective Parameter Estimates for an Ad Hoc Productive Capacity Model	200
D-III.	Hypothetical Organization for Second Order Polynomial Elicitation	204
D-IV.	Subjective Estimates of Productive Capacity Associated with Various Manning Levels . . .	205
D-V.	Summary of Regression Results	211
D-VI.	Second Order Polynomial Model Test Results	216

Abstract

This study formulates a methodology for evaluating alternative proposals to alleviate the Air Force's Development Engineering (28XX) officer shortage. Compensation was selected as the decision variable from 18 factors related to engineering officer career intent. A compendium of pertinent studies reviewed was also provided. The 28XX officer responses to the most recent Air Force Quality of Life Survey indicate that salary has substantial influence on career motivation. The value, or productive capacity of the 28XX officer force was assumed to be a function of the numbers of Lieutenants, Captains, and Field Grade Officers assigned. Data elicited from an experienced Development Engineering officer were fit to a second-order polynomial using stepwise regression to provide an approximate ordinal indicator of relative productive capacity. A System Dynamics model was constructed to provide force and cost projections based upon exogeneous inputs of the future demand for engineers and salary policies. The model's accession and retention rates respond positively to increases in the ratio of future expected military pay to future expected civilian pay. Uses of the model were illustrated, but more extensive validation and parameter estimation is required before the model can be used with confidence in formulating policies.

A SYSTEM DYNAMICS MODEL FOR ASSESSING THE
COST-EFFECTIVENESS OF USAF ENGINEERING
OFFICER COMPENSATION POLICIES

I. Introduction

The most persistent concerns of Air Force leadership in the 1980s will be the retention, recruitment, and training of the individuals we need to accomplish our mission. Our fiscal year 79 experience clearly shows that we must put forth increased effort in terms of both resources and management initiatives if we are to be successful in satisfying these concerns . . .

. . . The most vital personnel issue today is the retention of our experienced people. . . . [E]ngineer . . . retention is well below our objectives.

With these remarks, Joseph C. Zengerle (1980), the Assistant Secretary of the Air Force (Manpower, Reserve Affairs, and Logistics), informed the House Armed Services Committee of his concern about a shortage of engineering officers in the Air Force. As shown in Table I, the Air Force's current scientific and engineering officer manning is only 85 percent of its authorizations, and the shortage has been projected to get worse between now and 1984. The decreasing engineer officer retention rates, depicted in Table II, have contributed to these current and forecasted shortages.

The deficit in military engineering manpower is just part of the story. The Air Force's civilian engineer manning has an even larger deficit overall, so that civilian

TABLE I

MILITARY MANNING PROJECTIONS FOR OFFICERS IN
CAREER FIELDS 26XX, 27XX, 305X, and 55XX*
(Government Executive, 1980b;
Original Source: AFMPC)

	FY80	FY81	FY82	FY83	FY84
Requirement	7676	7676	7676	7676	7676
Inventory	6492	6317	6235	6254	6305
Manning Percentage	85%	82%	81%	81%	82%
Deficit	1184	1359	1441	1422	1371

*26XX - Scientist
27XX - Acquisition Manager
28XX - Development Engineer
305X - Communications Electronics Engineer
55XX - Civil Engineer

TABLE II

OFFICER RETENTION: ENGINEER RATES COMPARED TO
ALL SUPPORT OFFICERS (AFMPC, 1979)
(4-11 Year Group)

<u>Engineering Officers</u>			
	<u>FY77</u>	<u>FY88</u>	<u>FY79</u>
Development	63.3%	59.9%	49.9%
Scientific	71.2	70.0	47.3
Civil	60.0	60.1	46.7
Comm/Elec	67.5	57.1	55.2
Overall	65.5	61.8	49.8

Support Officers

<u>June 77</u>	<u>June 78</u>	<u>June 79</u>
60.0%	65.8%	56.9%

NOTE: The retention rate for a year group is the number of officers remaining on active duty through eleven years as a percentage of the number in the year group after four years of service.

engineers cannot take up the slack for the military shortfall. The Air Force's overall engineering manning, summarized in Table III, falls 17 percent below its authorized strength.

TABLE III

AIR FORCE TOTAL ENGINEERING AUTHORIZATIONS/MANNING
(Przemieniecki, 1980:8)

	Authorized	Assigned	% Manning	Shortage
Military	7,489 (40%)	6,266 (40%)	84	1,223
Civilian	<u>11,298 (60%)</u>	<u>9,321 (60%)</u>	<u>83</u>	<u>1,977</u>
Totals	18,787 (100%)	15,587 (100%)	83	3,200

Although comparisons of engineering manpower to the number of authorized billets can be useful indicators of the Air Force's capabilities, such comparisons alone are not entirely adequate. What is ultimately required by the Air Force is not just a specific number of engineering bodies, but a technological capacity to support national security objectives. The capacity available to the Air Force depends not only upon the number of engineers assigned but also on how closely their skills correspond to those required by the Air Force and on how productive they are in their skills. Productivity is, in turn, a function of such factors as experience, education, and motivation.

General Lew Allen, Jr. (1979:73,74), the Air Force Chief of Staff, described the Air Force's needs for technological capacity in the following comments.

From the perspective of national security, the significance of technology and technically competent people cannot be overstated--they provide the critical edge in our enduring competition with the Soviet Union. The Soviets have long been aware of and determined to overcome the U.S. lead in military technology. For years, they sought to compensate for their qualitative shortcomings by fielding massive numbers of both men and machines while also striving to close the gap in weapons technology. Today, we see mounting evidence that their sustained, well-funded efforts over the past decade have enabled the Soviets to seriously challenge and in some cases surpass the U.S. in several fields of weapons technology. . . .

The implications of this challenge are ominous and must be countered. The urgency is particularly compelling for the U.S. Air Force. Recent history of aerial combat has made clear that success or failure over the modern battlefield is directly related to the technological capabilities of the combatants. We are committed to maintaining the qualitative edge long enjoyed by our combat forces, an edge which translates today into such force multiplier systems as the AWACS [Airborne Warning and Control System], multi-role aircraft, and sophisticated intelligence gathering systems.

The foundation of our technological superiority is people--high quality, highly educated people.

In addition to the shortfall in total engineering manpower, the Air Force has discrepancies between authorized and assigned strengths of the more experienced grade levels. These discrepancies are evident in the Development Engineer Officer career field (Air Force Specialties 28XX) manning shown in Table IV. According to Lieutenant General Lawrence A. Skantze (Government Executive, 1980a), Commander of Systems Command's Aeronautical Systems Division,

When you put the experience equation in there along with the body-for-body reduction, it's a disaster. . . . You can't maintain superiority in technical excellence of equipment if you don't maintain excellence in people.

The factors mentioned so far support the proposition that the retention rate for engineering officers

TABLE IV
DEVELOPMENT ENGINEER OFFICER MANNING BY GRADE
(AFMPC, 1980b) (As of September 1980)

Grade	Authorized	Assigned	Manned
Colonel	124	100	81%
Lieutenant Colonel	563	491	87%
Major	935	808	86%
Captain	2362	1409	60%
Lieutenant	<u>533</u>	<u>1042</u>	<u>195%</u>
Total	4517	3850	85%

influences the Air Force's technological capacity in several ways. First, higher retention rates can enable the Air Force to fill the total number of engineering officer billets if current accession rates are held constant. (Of course, higher accession rates could do this as well.) Second, the retention rate determines the average experience levels which in turn influence the average productivity of the engineering officer force. And finally, low retention directly contributes to high turnover which hampers productivity. Personnel moving into positions vacated by attrition are less productive as they adjust to their new positions. In addition, the supervisors and trainers of these replacements "also have their direct job productivity decreased substantially [Roberts, 1964:135]." From such considerations as these, it is easy to see the potential impact which retention policies can have on the

Air Force's ability to obtain its technological capacity requirements.

The Dean of the Air Force Institute of Technology's School of Engineering, Dr. J. S. Przemieniecki (1980) recently reported that

This engineering manpower shortage is not unique to the Air Force. It is a national problem that could become a major roadblock to the badly needed improvements in the U.S. productivity and innovation which could ultimately lead to a serious deterioration of national security.

In this context, the Air Force should be concerned about the broader implications of the adequacy of the nation's technical manpower, particularly with regard to national security. As indicated in General Allen's remarks, an American shortage of engineers can pose a national security problem, especially when America's engineers devoted to defense programs are compared with the Soviet Union's. (Such comparisons are discussed later in this chapter.)

Actually, the Air Force's technological capacity is provided by all military and civilian technical personnel, the associated support personnel and capital resources. This study will focus upon one part of this overall capacity, that provided by officers in the Development Engineer Utilization Field (Air Force Specialty Code 28XX). Accordingly, "productive capacity" will be used to mean the research and development capabilities provided

by officers up through the rank of Lieutenant Colonel assigned to 28XX specialty code positions.

Furthermore, this study will focus upon retention policies as one of several categories of methods to enhance the technological capacity associated with the development engineer officer force. Since "improved retention" of development engineering officers is likely to alleviate the Air Force's shortfall in technological capacity, it seems appropriate to devote some effort toward a better understanding of retention policies. To formulate policies for improving retention, decision makers must consider the interrelationships between incentives, costs, civilian sector competition, development engineer manning levels, productivity, and technological capacity. The model described in this report is designed to incorporate these relationships as an aid in selecting between alternative retention policies. To choose between such alternatives, two of the pertinent questions to ask are: (1) What policies will provide the Air Force a development engineer officer work force capable of supporting national security objectives? and (2) Which policies will yield the most capability for a given cost?

Purpose of This Thesis

This thesis is intended to provide a greater understanding of the effects of retention incentives on the Air Force's technological capacity. The specific problem

addressed is to formulate a methodology for evaluating alternative policies proposed to alleviate the Air Force's development engineer officer shortage. The point of view taken in the approach to this problem is that of an Air Force-wide personnel manager as distinguished from that of a research and development (R&D) manager. That is to say, this study focuses on policies to provide to R&D organizations the engineering manpower with the potential productivity required to perform their missions. It does not emphasize the use of this potential.¹

Objectives of the Study

The objectives of the research described in this report were:

1. To develop a list of propositions which can be used by the Air Force in formulating retention policy initiatives.
2. To develop a measure of effectiveness, or productive capacity, as a function of the numbers of development engineering officers assigned to each grade.
3. To construct a System Dynamics model for use in assessing the impact over time of compensation policies on the costs and capacity of the Air Force's Development Engineering officer force.

¹Readers seeking more effective methods for R&D management may find Robert's (1964) The Dynamics of Research and Development worthwhile.

The primary purpose for pursuing these objectives is to provide information and techniques to assist in formulating policies to alleviate the stated shortage in the Air Force's military engineering manpower. The discussions so far have implicitly assumed that the Air Force's authorizations for engineers reflect valid requirements. Of course, this is one of the debatable aspects of the problem statement. In fact, since the Air Force's stated manpower requirements have traditionally exceeded the resources allocated to it (USAFPP, Vol. I., 1975), some may regard these statements of need with some skepticism. Certainly the validity of this stated shortfall should be addressed.

Is There Really a Shortage
of Engineers?

The answer to this question may depend upon how "shortage" is defined. The following paragraphs discuss three commonly used definitions extracted from The Demand and Supply of Scientific Personnel by Blank and Stigler (1957:23-33).

The "Manning Less Than Authorized" Shortage. "In one sense, there is a shortage of members of a particular profession if the actual number is less than the number dictated by some social criterion or goal [Blank and Stigler, 1957:23]." In this first definition, the criterion used is the level of engineering authorizations approved through the Air Force manpower channels. Whenever the

numbers of assigned personnel are less than the authorized level, a shortage exists under this definition. This is the definition used previously in this report as reflected in Tables I and III. Obviously, there is a shortage by this definition.

But there are problems with this definition of shortage. One is that it depends upon the definition of engineering officer. The definition of engineering officer implied in Table I is an officer assigned to one of the following Air Force Specialty Codes (AFSCs): 27XX, System Acquisition Management; 28XX, Development Engineering; 305X, Communications-Electronics (Engineering); and 55XX, Civil Engineering. All of these career areas except 27XX require a bachelor's degree in engineering and involve engineering work directly or at least require engineering knowledge. The 27XX career area requires a degree in either engineering, management or science (AFR 36-1, 1980: A10-31, A10-34).

Another common definition of engineering officer is any officer who has completed an engineering degree. There are over 16,000 officers in the Air Force fitting this definition (Gaffney, 1980b). Comparing this number to the 7,676 positions in the engineering specialties mentioned above can lead one to believe that the Air Force has a distribution problem instead of a shortage. But engineers are also used in twenty-four other career areas which list

engineering among the degrees which are preferred to fulfill their educational requirements (AFR 36-1, 1980).

It appears that these engineers are needed in these other career areas. This was demonstrated by an extensive program to identify qualified and available officers to "cross-flow" into the engineering specialties. This program contributed only 1 percent in one year to the manning of the engineering specialties (Mackey, 1980). So, at best, redistribution should be viewed as only a partial solution to the shortage of officers in the specialties specifically requiring engineers. Accordingly, for the rest of this study, the term "engineering officer" will be used to mean an officer assigned to a career area which specifically requires an engineering degree; i.e., a 28XX, 305XX, or 55XX duty Air Force Specialty Code (AFSC).

Another perplexity associated with the "less than authorized" definition of shortage is that it assumes that the Air Force's approved authorizations are valid, in the first place and in the second place, that other personnel cannot be readily substituted for engineers. These assumptions appear to be defensible in light of the authorization approval process which "uses proven industrial engineering methods and techniques to document mission requirements and determine associated manpower levels [Doren, 1976:30]." However, there is also evidence indicating that these assumptions should be questioned. For example, in a recent survey (Ginnett and Graviss, 1979) of Air Force Systems

Command military and civilian engineers, 26 percent indicated that their job did not require an engineer; 43 percent indicated that their job involved engineering less than 20 percent of the time; and 74 percent indicated that engineering took less than 50 percent of their time. The Air Force Management Engineering Agency is conducting a study to determine the Air Force engineering and scientific manpower requirements more precisely (Przemieniecki, 1980:11). The results of this study are expected in March 1981 (Koenig, 1980). In the interim, current approved authorization levels provide the best available data on the Air Force's engineering manpower requirements.

The "Compared to Russia" Shortage. Another criterion which could be used to define an engineer shortage is that we should have sufficient engineers to compete effectively with the Soviet Union. This is the criterion General Alton D. Slay (1979b:11), Commander of the Air Force Systems Command, implied in the following remarks:

. . . in 1959 we in the United States graduated about 40,000 engineers. Now we're only graduating about 50,000. At that same time, 1959, the Soviets graduated 75,000 engineers, not quite twice what we did. And in 1969, ten years later, they graduated 190,000; almost five times as many as we did. And in 1979 they graduated just under 300,000, six times as many as we did. Ten years ago, in 1969, we and the Soviet Union each had that 575,000 men and women engineers engaged in R&D in the country. As I mentioned earlier, we still have that number, but the Soviet Union currently has 1,300,000, just a little over that. So in those ten years they've more than doubled, while we've stayed static. Also as an item of interest to this particular audience, today we have just over 170,000 scientists

and engineers in research and development directly related to defense. The Soviet Union has about 510,000 in those same pursuits.

. . . we've long maintained that we don't have to match the Soviet Union in quantity of weapons because our quality is better and that makes the difference. The question that I've been asking myself and others recently, are we too glib in making that assertion. Can we be sure today that one engineer or one scientist engaged in R&D on military systems in the United States is as good as three engineers engaged in similar projects in the Soviet Union? And if we are and if we can match them today, how long will that remain so considering the fact that they are turning out engineers at six times our rate?

These comparisons of engineering manpower clearly point out a deficit under the "compared to Russia" definition. But a more careful analysis is needed to assess the relative technological capabilities of the U.S. and the USSR. In an article which cites manpower figures similar to those expressed above, Heuer (1980), an Air Force Systems Command Foreign Technology Division analyst, explains,

Comparisons such as those presented above may be misleading . . . because the Soviets count all persons who have received an engineering degree as engineers, regardless of their employment. Also, the Soviet definition of "engineering" includes . . . fields . . . which would not be considered engineering in the US. . . . Many engineers in the USSR have received their undergraduate degrees through evening or correspondence programs, which are acknowledged to be inferior to full time programs.⁴ . . . Furthermore, . . . doubts on the wisdom of training so many engineers have even been

⁴This inferior quality is not descriptive of the education provided the Soviet military officers, however. The Soviet Union has an impressive educational system for their officers with 134 schools comparable to the U.S. service academies. Their excellence is maintained by competitive selection of students (with three applicants per opening), high quality facilities, extensive laboratories, close association with the Soviet Academy of Sciences, and a high degree of specialization (Przemieniecki, 1980:23-24).

expressed by Soviet commentators. . . . "[F]or equivalent volumes of production and introduction of new technology [the Americans] use 3 to 4 times fewer designers and researchers than we do. . . ."

The point, of course, is not that one should dismiss these Soviet manpower figures as hopelessly exaggerated. Rather, one must be cautious in drawing conclusions about Soviet and American potential for scientific advancement based on simple comparisons of a few manpower series at a point in time. Manpower series should be examined in the light of what is known of other indicators used to assess R&D capabilities. One such indicator is the number of Nobel Prizes received by various nations. A pertinent fact is that from 1946 to 1976 the U.S. accounted for 85 Nobel Prize laureates in chemistry, physics, and physiology/medicine, out of a total of 171, while the U.S.S.R. accounted for only 7.

In short, this Soviet army of scientists and engineers may be a sign of systematic weaknesses as well as strengths [p. 37]. . . .

Analysis of present trends in Soviet S&T manpower and educational policies indicates that the current requirement is to turn from extensive (e.g., growth in the numbers of workers and increase in investments) to improving the organization of work involving research workers, professors, and students) [p. 40].

But, "What happens if, and when, the Soviets identify and solve those weaknesses [p. 34]?"

In short, other constraints prevent the Soviet Union from overwhelming the United States in the technological race. But since they are not at all constrained by the availability of engineering manpower as the U.S. appears to be, one can conclude that there is a shortage of engineers under the "compared to Russia" definition as well.

The "Supply versus Demand" Shortage. Blank and Stiger (1957:24) also proposed that another

. . . meaning of shortage, and the one that is most natural in an economy with a free labor market, is that a shortage exists when the number of workers available

(the supply) increases less rapidly than the number demanded at the salaries paid in the recent past. Then salaries will rise, and activities which once were performed by (say) engineers must now be performed by a class of workers who are less well trained and less expensive.

To determine if a shortage existed prior to 1955, Blank and Stigler (1957:23-33) analyzed the trends in engineers' earnings relative to other occupations and evaluated the market to determine if the free competition assumption was valid. They concluded first that the market was competitive so that a shortage of engineers should be accompanied by salary increases higher than other occupations. But their data showed that, with the exception of the Korean War years, the ratio of wages paid engineers to the wages paid other occupations steadily decreased from 1929 to 1954. Therefore, Blank and Stigler concluded that for the two and one-half decades prior to 1955, there was no shortage of engineers.

Using essentially the same technique with more recent data yields somewhat different results. The average annual salary increases for non-government engineers are compared with the increases for other non-government employees in Figure 1. Overall, the increases for all occupations included in the annual National Survey of Professional, Administrative, Technical, and Clerical Pay correlates closely with the increases in engineer salaries. But, for the first time in the history of the survey,



Fig. 1. Comparison of Non-government Engineers' Salary Increases to Other Occupations. (Source: National Survey of Professional, Administrative, Technical and Clerical Pay, Bureau of Labor Statistics, 1979:3; and Smith, 1980)

engineers have been given higher increases for three consecutive years. These relatively higher increases for engineers in 1978, 1979, and 1980 indicate a national shortage of engineers, especially when compared to the generally lower increases in earlier years.

Furthermore, an analysis of the expected output from America's engineering educational institutions and the likely demand for engineers indicates that the national engineer shortage is likely to continue through the 1980s (Przemieniecki, 1980:1-6; and Deutch, 1979). For these reasons, President Carter recently requested the Secretary of Education and the Director of the National Science Foundation to review our science and engineering education policies (Przemieniecki, 1980:1).

The discussion so far under this definition refers only to the civilian community while the primary concern of this study is whether there is a shortage of engineers in the Air Force. Blank and Stigler (1957:23,33) also indicated that if wages are not allowed to respond to the demand, then those sectors which hold down wages will suffer a shortage. From 1974 to 1979 civilian engineer salaries have increased at a pace 1.3 percent below the inflation rate (Bureau of Labor Statistics, 1979; and Smith, 1980), but regular military compensation has increased at a rate 14 percent below the inflation rate (Laird, 1980). This has resulted in the disparity between the salaries for

engineering officers and their civilian counterparts depicted in Figure 2. Applying Blank and Stigler's definition under this situation would lead one to conclude that there is a shortage of engineers throughout the military sector.

It should be noted that the salaries for both the civilian engineers and military officers presented in Figure 2 represent only part of total compensation. The complexities involved in comparing total compensation accounting for fringe benefits, tax advantages and the like is well demonstrated by Gussow (1966). Unfortunately, the comparisons included in his study are out of date.

Since the Air Force does not pay higher salaries for engineering officers with advanced degrees, the differential is even greater for those officers holding a master's or a doctorate degree. One should note, however, that, unlike many employers, the Air Force allows some engineering officers to pursue tuition-free education toward an advanced degree while still receiving full salary. Officers accepting these educational benefits incur a commitment to stay in the Air Force for a period up to three times the number of months spent in school (AFR 36-51, 1980:8). It seems sensible for some wage disparity to exist between officers who received such benefits and their civilian counterparts who did not.

One could also argue that the discrepancy in wages is offset by the "psychic income" an officer receives from

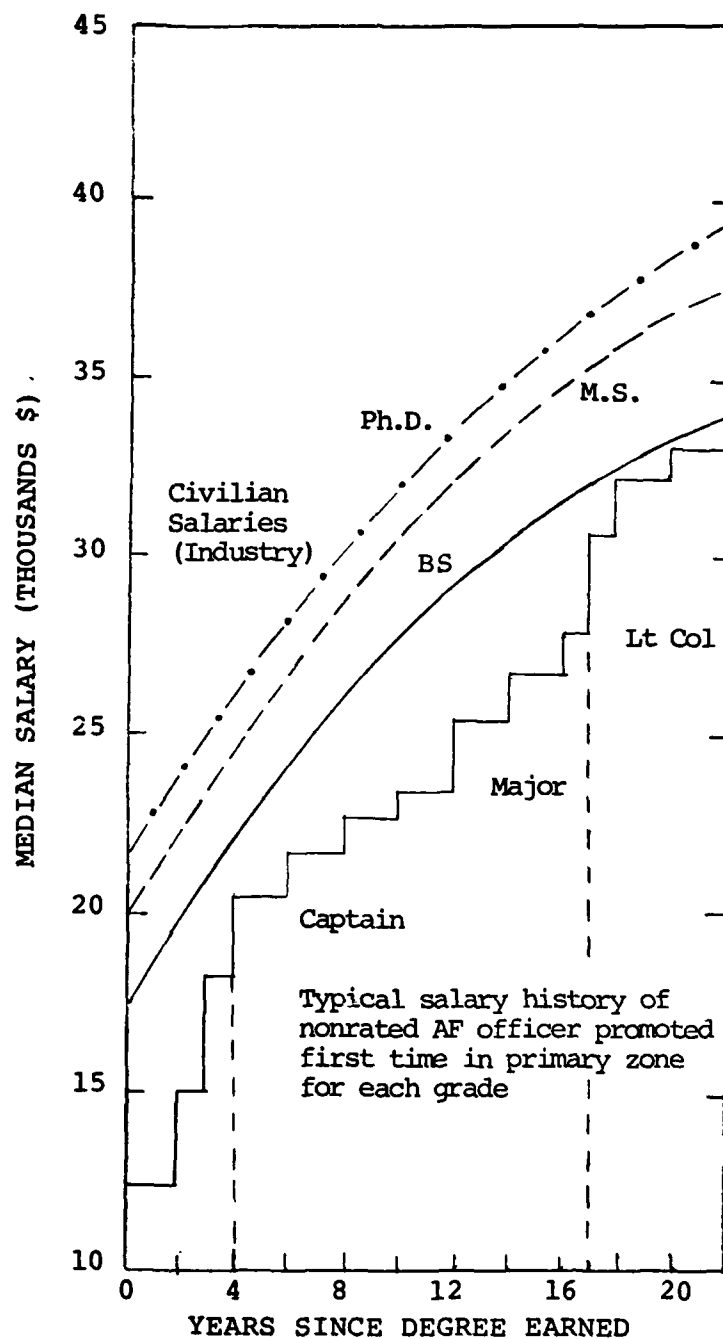


Fig. 2. Comparison of Civilian Engineering Median Salaries With Military Pay. (Source: Engineering Manpower Commission Bulletin No. 43, March 1979, and Officer Pay Guide, 1979 (Przemieniecki, 1980:15))

serving his or her country. But unless this "psychic income" is increased or the requirements for engineers decreased, the Air Force would still suffer a deficit after a period when civilian engineer's salaries increase more rapidly than military engineers'.

In a free market economy, whenever the demand for engineers exceeds the supply, employment incentives will increase to ration the existing supply among those employers willing and able to pay the new equilibrium level of incentives (Ferguson and Gould, 1975:227). Therefore, whenever the Air Force is unable or unwilling to increase engineer officer incentives in response to increased demand for a limited supply of engineers, they will lose engineers to the civilian sector. In such situations, the U.S. economic system, in effect, places higher priority on allocating engineers to produce private sector goods than to pursue national security objectives.

While at the same time, the Soviet Union's centrally planned economy places priority on defense research and development to the obvious detriment of consumer demand. The Russians (Smith, 1976) vividly portrays the plight of the average consumer in the U.S.S.R. This higher priority is also evident in the manpower estimates cited earlier (Slay, 1979b) indicating that the Soviet Union has 2.3 times more engineers than the U.S. but devotes three times as many to defense research and development.

Summary. This section started by asking if there really is a shortage of engineering officers in the Air Force. To address this question three different definitions were considered: the "manning less than authorized" shortage, the "compared to Russia" shortage, and the "supply versus demand" shortage. The discussion under these definitions indicated that regardless of the definition used, there is cause for concern about a shortage of engineering officers in the Air Force.

The Air Force's authorizations for engineers provide the best available indicator of technological capacity requirements since they indicate grade levels as well as total numbers. Therefore, the "manning less than authorized" shortage will be used for the remainder of this study when referring to a manning shortage. Of course, the real concern of the study is the shortage of technological capacity which is hypothesized to be the combined result of the manning of development engineer officers and the match between their skills and the Air Force's needs.

What Can be Done About the Shortage?

As indicated earlier, the ultimate objective addressed in this report is to provide the Air Force sufficient engineering capacity. A conceptualization of the means of providing sufficient capacity is illustrated in Figure 3. First, how much capacity is sufficient? Answering this question requires a painstaking, never-ending, subjective

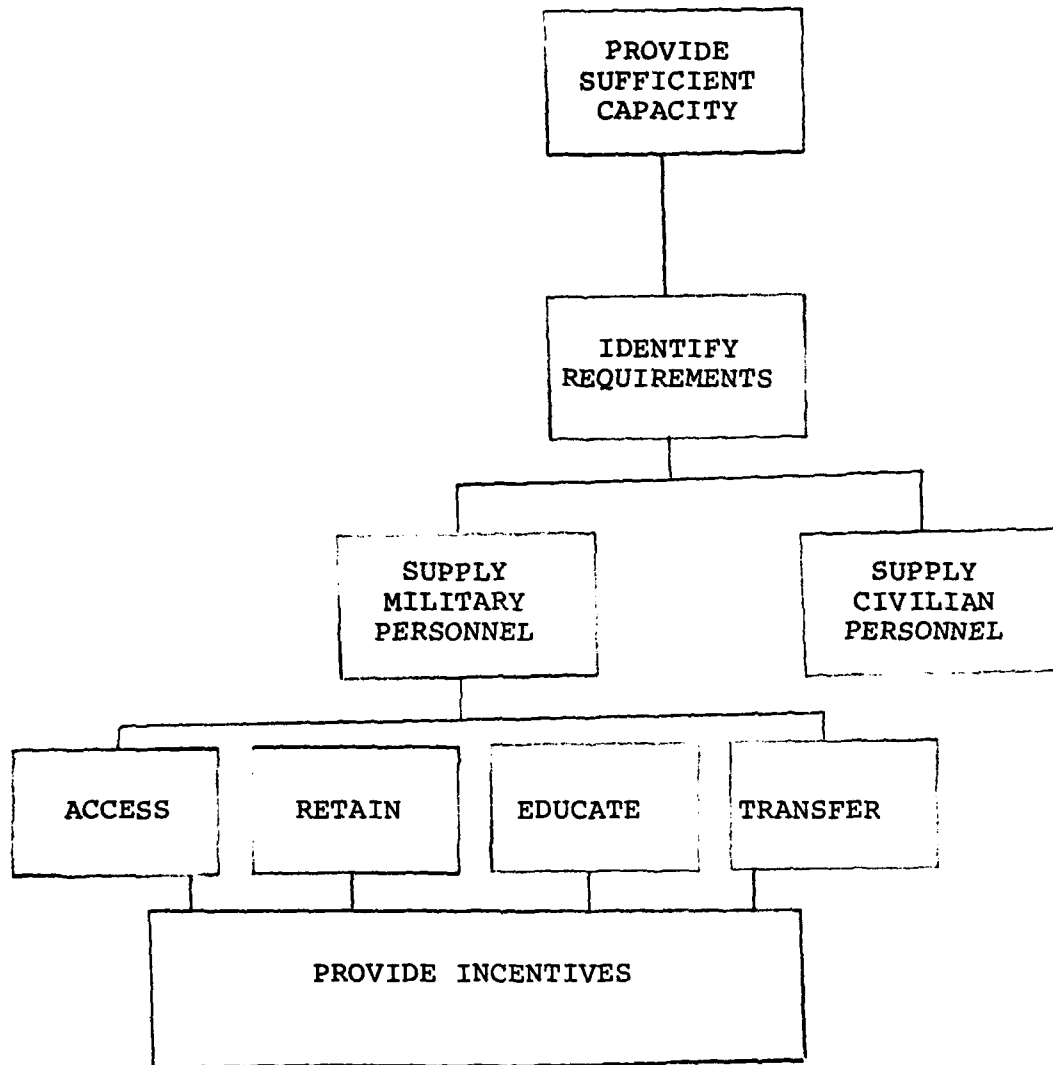


Fig. 3. Conceptualization of Engineering Capacity Provision Process

and controversial process of striving to determine the resources needed to achieve national objectives most efficiently. The engineering authorizations approved for the Air Force can be viewed as a result of this process and, at any time, represent the best detailed indicator of the Air Force's engineering manpower requirements. But these requirements can be influenced by the shortage of engineers. As engineers become scarce, it becomes more efficient to provide more non-engineer resources to increase the productivity of the limited supply of engineers and to concentrate their efforts on the tasks requiring engineering skills (Blank and Stigler, 1957:24). As mentioned earlier, the Air Force Management Engineering Agency is conducting a study to test the current validity of the Air Force's engineering and scientific manpower requirements and to determine more efficient manpower structures if necessary (Koenig, 1980).

As part of the requirements identification process, the total requirements are classified into military and civilian categories, grade levels, and specialties. After this, the military and civilian personnel systems operate relatively autonomously to fill the authorized positions as nearly as possible with people having the qualifications specified by the requirements identification process. For military personnel this requires a coordinated effort to recruit new engineers, retain qualified engineers currently on board, transfer in qualified engineers from other

specialties, and educate other people to meet qualification requirements. Much is being done in each of these areas to work the engineer shortage problem. (For a concise list of current Air Force initiatives see Przemieniecki, 1980:B-1/2.)

This research will focus primarily upon retention of the military component of the Air Force's engineering capacity. Unfortunately, retention policies cannot be considered entirely in isolation since accession, retention, education, and redistribution are all interdependent. For instance, the number of accessions required depends upon the number of officers retained and the number cross-trained into engineering specialties. Similarly, incentives designed to encourage one response such as staying in the Air Force will often influence other forms of behavior such as joining the Air Force. Some incentives which influence retention could also have a dramatic effect upon the productivity of assigned personnel (Vincent and Mirakhor, 1972: 192 [summarized in Appendix A]).

The key word in this discussion is incentive. Appropriate incentives are necessary to attract and/or retain people for critically manned specialties. In this context, "incentive" is used to mean any inducement to motivate a sufficient quantity of people with required qualifications to do what we need them to do; i.e., join, stay in, etc. The draft, pay, and job satisfaction are examples of incentives in this context. Obviously, incentives are necessary to provide any manpower capability.

What is controversial is the nature and extent of the incentives to be offered for critically manned specialties.

This research is intended to improve our understanding of engineering officers' responses to incentives and the impact of their response on the Air Force's engineering capacity. In particular, the study addresses the long-term effects of specific incentives which can be initiated by the national leadership (Congress, Secretary of Defense, Headquarters USAF, etc.). Even though it is not possible to isolate the effects completely, the study emphasizes those incentives primarily designed for retention as opposed to accession of engineering officers.

The effects of primary interest are those associated with the Air Force's military engineering capacity. But decision makers must also consider, at least qualitatively, the effects upon the total Air Force R&D capacity and the nation's technological development, especially in defense-related programs.

Approach of the Study

The approach for this research was adopted from "The Principles and Procedures of Systems Analysis" by E. S. Quade (1977) and Industrial Dynamics by Jay W. Forrester (1961). Quade (p. 33) indicates that the process of

. . . analysis advances (by iteration or successive approximation) through something like the following stages:

[1] Formulation (The Conceptual Phase). Clarifying the objectives, defining the issues of concern, limiting the problem.

[2] Search (The Research Phase). Looking for data and relationships, as well as alternative programs of action that have some chance of solving the problem.

[3] Evaluation (The Analytic Phase). Building various models, using them to predict the consequences that are likely to follow from each choice of alternatives, and then comparing the alternatives in terms of these consequences.

[4] Interpretation (The Judgmental Phase). Using the predictions obtained from the models and whatever other information or insight is relevant to compare the alternatives further, derive conclusions about them, and indicate a course of action.

[5] Verification (The Scientific Phase). Testing the conclusions by experiment.

The results of the formulation stage have already been discussed. As previously defined, the problem is to build a model which can be used to evaluate alternative policies oriented toward retention of development engineering officers. Thus this research relates to only the first three of the stages described above.

The search stage involved a literature review of pertinent studies and an analysis of development engineer responses to the "Quality of Air Force Life" survey. This research was performed to develop a list of propositions explaining development engineering officer attrition and to identify which factors are the most important determinants of career intent. Based on this research, compensation was selected as the primary decision variable determined by the different alternatives to be evaluated.

The modeling technique employed for the evaluation phase was System Dynamics. System

. . . Dynamics is particularly suited for the study of complex systems problems, in which a multitude of factors are interrelated through organizational information feedback paths. It is similarly aimed at dynamic problems in which the process tends to evolve and reveal itself over a period of time [Roberts, 1964:xx].

The primary interest in this study, the technological capacity of development engineering officers, is a function of many interrelated factors. And the key consequences of concern are the expected future responses of technological capacity and costs to alternative retention policies. These two considerations alone constitute considerable cause for selecting the System Dynamics methodology.

Another advantage of System Dynamics is that DYNAMO, the computer programming language for System Dynamics models, is based primarily on two types of variables: "levels" and "flows." This System Dynamics structure provides a point of view for thinking about the real personnel system under investigation. For example, a simplified concept of the development engineer officer system is depicted in Figure 4. Under this construct, officers are viewed as being aggregated in "levels" (the boxes associated with their rank) and the levels at any time are determined by the previous rates of flow (represented by arrows) into or out of each level. The rates of flow can depend upon the values of other variables included in the system to reflect different hypothesized relationships or proposed policy alternatives. This construct will be described in more detail in Chapter III. But suffice it to say for now, that System

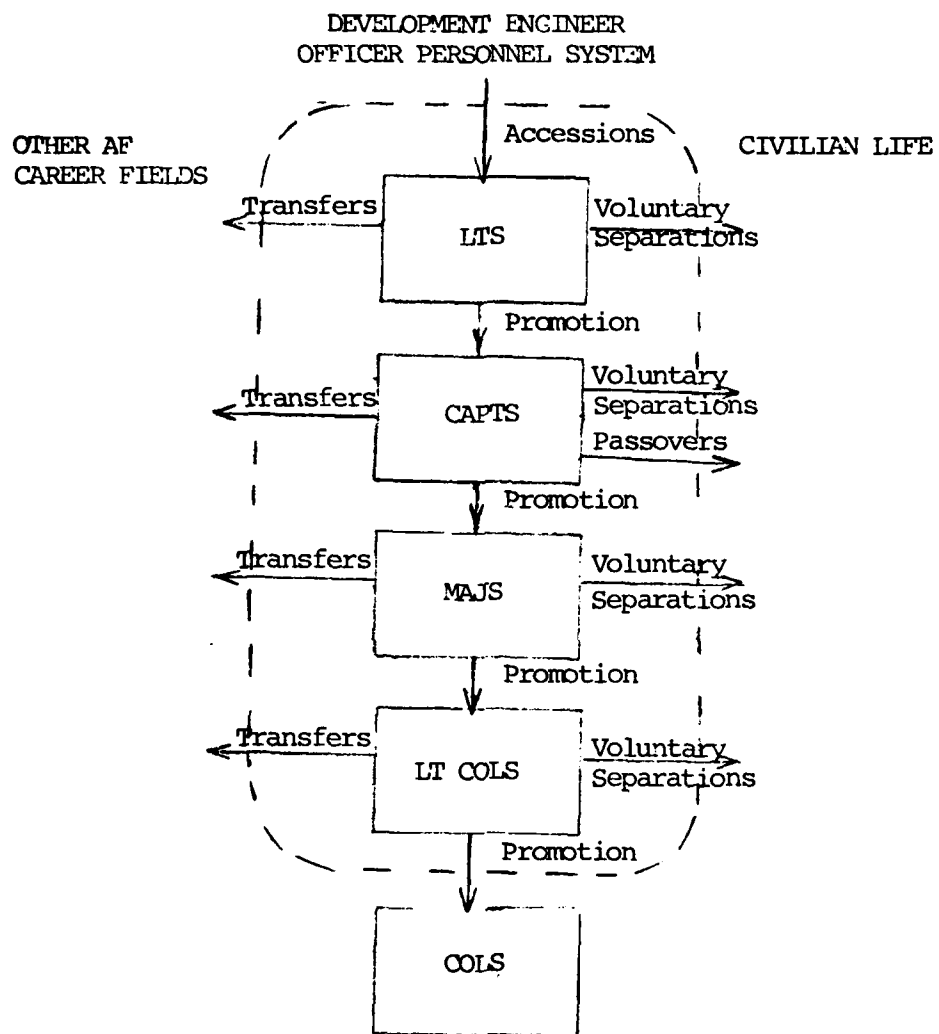


Fig. 4. Model Conceptualization

Dynamics provides extremely flexible and useful techniques for simulating personnel systems such as the one considered in this research.

One potential weakness of the System Dynamics approach is that it forces the analyst to consider flows and levels at some degree of aggregation. For instance, it would not be feasible to handle individual officer transactions with distinct attributes for each officer. It turns out that this does not present a problem for this study. In this regard, the model for this research resembles one constructed by Carpenter and Lacey (1977:28) to analyze military retirement issues. In describing their model they indicated that

Obviously, personnel management decision making is far more complex than is indicated here. The level of abstraction is indicated, however, because a very large proportion of the decision making activities involve a relatively small number of exceptional problems and events. Their effect on aggregate behavior is probably very small. Since the purpose of the model was only to indicate overall trends in the system, it was necessary to capture only the structure of the major policies, whose form and effects persist for many years. A high degree of aggregation was specified in this model so that the important dynamics of the complete system could be analyzed without becoming bogged down in details.

At the same time, however, the degree of aggregation must be scrutinized to insure that all the salient considerations are included.

Development of any System Dynamics model progresses through several steps proposed by Forrester (1961: 13). These steps actually encompass the stages recommended

by Quade. Forrester's steps are grouped by Roberts (1964: xx-xxii) into seven different phases.

The first phase is the identification of a key industrial or economic problem that appears to merit dynamic system-oriented investigation. . . .

The second stage of [a System] . . . Dynamics study consists of the development of a verbal theory of cause-and-effect interaction and a verbal description of the decision policies in effect in the system being studied. . . .

The next phase . . . requires the construction of a mathematical model of the . . . system [being investigated]. . . . This model is intended to add much precision to, and hence enhanced understanding of, the descriptive and theoretical portions of [the study].

. . . . The fourth phase of development of [a System] . . . Dynamics investigation is the generation over time of the behavior of the modeled system. Digital-computer simulation techniques are used for the study of the . . . model, results are compared with available knowledge about . . . [the Air Force personnel system], and the model is revised until it seems acceptable for more intensive study of the actual system. . . . [M]ore detailed simulation experimentation . . . constitutes stage five of a typical . . . [System] Dynamics study.

. . . . A sixth phase of research . . . involves incorporation into the model of redesigned system parameters or policies, followed by computer runs to determine their effect on the outcomes. . . .

Finally, . . . [a System] Dynamics study of a real organization ought to attempt improvement upon it, as indicated by the model experimentation.

As part of the System Dynamics process, the computer model described in this report is designed for evaluating proposals related to the total salaries paid to engineering officers. The consequences estimated by the model for an alternative are based on a particular scenario which starts with the present state of the world and shows, step by step, how a future situation might evolve (Quade, 1977:43). For this study, the state relates to the demand for engineers

in both the civilian sector and the Air Force. Since there is considerable uncertainty about this future state of the world, the model is designed so that each alternative can be evaluated under several different scenarios representing a range of realistic expected engineer demand levels.

Using the model constructed during this project, a more complete system dynamics analysis could proceed with the interpretation and the verification phase.

The progress toward achieving the research objectives is reported as follows.

Overview of the Report

The results of the review of engineering officer motivation studies are described in summarized form in Chapter II. More detailed extracts and descriptions of individual studies are provided in Appendix A. Similarly, an analysis of development engineering officer responses to the Air Force Quality of Life Survey is described in Chapter II with supporting data included in Appendix C.

Chapter III describes the System Dynamics model designed to help policy makers evaluate alternative engineer officer compensation proposals. Chapter III also illustrates some potential applications of the model. The flow diagram and a listing of the computer program are provided in Appendix B. Appendix D describes the development of the productive capacity function which is included in

the model as the primary "bottom-line" indicator of effectiveness.

Chapter IV summarizes the major research findings and provides recommendations for follow-on research.

II. Incentives

The question addressed in this chapter is: What motivates engineering officers to stay in the Air Force? This question has received a considerable amount of research attention. Therefore, this chapter consists primarily of a brief summary of the motivation literature reviewed for this study. Additional details extracted from some of the more pertinent studies are provided in Appendix A. Following the literature review is a presentation of the Development Engineer Officer responses compared with all officer responses to the most recent Air Force Quality of Life Survey.

Literature Review

The review of literature pertaining to engineering officer career motivation provided support for the following propositions:

1. Utilization of engineering officers' skills and knowledge decreases their propensity to leave the Air Force (Mosbach and Scanlon, 1979; Lewis, 1978; McAbee, et al., 1961).
2. Challenging jobs decrease the incumbents' propensity to leave the Air Force (Mosbach and Scanlon, 1979; Lewis, 1978; Tuttle and Hazel, 1973; Vrooman, 1976; Patterson, 1977).

3. Feelings of self fulfillment, personal growth and accomplishment with respect to duty, decrease the propensity to leave (Lewis, 1978; Vrooman, 1976; Patterson, 1977; Downey, et al., 1964; Richard, 1972; Tuttle and Hazel, 1973).

4. Fair and unbiased performance evaluations tend to decrease the propensity to leave (Lewis, 1978; McAbee, 1961).

5. Recognition for superior performance tends to decrease the propensity to leave (Mosbach and Scanlon, 1979; Lewis, 1978; Downey, 1964; Tuttle and Hazel, 1973).

6. Engineers given greater autonomy in their job are less apt to separate (Lewis, 1978).

7. Family attitudes favorable toward the Air Force decrease the propensity to leave (Mosbach and Scanlon, 1979; Lewis, 1978; Thomas, 1970).

8. Frequent relocations tend to increase the engineer's propensity to leave the Air Force (Mosbach and Scanlon, 1979; Lewis, 1978; Downey, et al., 1964).

9. Duty requiring separation from one's family increases the propensity to leave (Mosbach and Scanlon, 1979; Lewis, 1978).

10. Retirement benefits tend to decrease the propensity to leave (Mosbach and Scanlon, 1979; Lewis, 1978; Patterson, 1977).

11. Promotions based on merit serve to decrease the propensity of engineers to leave (Mosbach and Scanlan, 1979; Downey et al., 1964; McAbee, 1961).

12. More rapid advancements decrease the propensity to leave (Downey, 1964; McAbee, 1961).

13. Salary increases, lower the propensity to leave (Mosbach and Scanlan, 1979; Lewis, 1978; Downey, et al., 1964; McAbee, 1961; Bluedorn, 1979; Tuttle and Hazel, 1973; Scanlan, 1976).

14. Officers given more "say" in their future assignments are more likely to stay in (Downey, 1964; McAbee, 1961).

15. Engineers who perceive their supervisors and the Air Force's leadership as being concerned, helpful and competent are more apt to stay in (Downey, et al., 1964; McAbee, et al., 1961; Vrooman, 1976; Patterson, 1977; Thomas, 1970).

16. Decreased prestige of the military as a profession tends to increase the propensity to leave (McAbee, et al., 1961; Tuttle and Hazel, 1973; Richard, 1972).

17. Enforcement of discipline in areas such as dress and appearance has a negative association with career intent (Mosbach and Scanlan, 1979; Lewis, 1978; Bluedorn, 1979).

18. An increase in civilian job opportunities increases the propensity to leave (Patterson, 1977; Bluedorn, 1979).

Of this list of propositions there are none which defy intuition or common experience. But which are the most important determinants of retention? The studies included in the literature review addressed this issue using different measures to rank the factors in order of their importance. Mosbach and Scanlan and Lewis ranked the factors in order of their significance in explaining the variation in career intent among different officers. Drysdale ranked the factors from surveys by Downey, et al. (1964) and McAbee (1961) in descending order of "leverage." High leverage represents those factors which survey respondents consider most important but which are not perceived as being available in the Air Force. The rankings of the factors from different surveys at different times with different samples using different criteria, quite understandably yielded different results as shown in Table V.

The results shown in this table and the propositions themselves represent a highly subjective amalgamation of the studies indicated. Appendix A provides a more detailed summary of a few of these studies and of other reports related to engineering officer motivation. The details of such studies are particularly important because the results depend upon the survey instrument and the criteria used for ranking the factors.

TABLE V
RANK ORDERING OF FACTORS BEARING ON CAREER INTENT

	Mosbach & Scanlon 1979(a)	Lewis 1978(b)	Lewis 1978(c)	Drysdale 1964(d)	Drysdale 1961(e)
1. Utilization	1		8		
2. Job Challenge	3		5		
3. Self-fulfillment/ Accomplishment		1	6		4
4. Performance Appraisals			2		
5. Recognition	9	8	7	6	
6. Autonomy			1		
7. Family Opinion	2	2			
8. Relocations	4	4		7	
9. Family Separation	8	7			
10. Retirement Benefits	6	3	4		
11. Merit Promotions	7			1}	1
12. Rapid Advancement				3}	2
13. Salary	10	5	3	5	3
14. "Say" in Assignments				2	6
15. Leadership/Supervision				4	5
16. Prestige					
17. Discipline					
18. Civilian Employment Opportunity	5	6			

Survey Samples: (a) 28XX officers in Systems Command; (b) Company Grade 26XX's (17%) and 28XX's (83%); (c) 26XX's and 28XX's with 4 years' service; (d) Former Air Force Institute of Technology Students, 2XXX's; (e) 25XX-57XX at the Air Proving Ground, Eglin AFB.

Analysis of the Air Force
Quality of Life Survey

This section provides a brief look at the responses of 28XX officers to selected questions included in the Air Force Quality of Life Survey. A total of 80 28XX officers responded to the survey; the breakout of these respondents by command and by grade is given in Appendix C.

The 28XX officer responses were weighted to correct for the proportionally greater representation of the higher grades, caused by the sample selection procedure. The details of this weighting procedure and the survey's administration and background are explained by McNichols, et al. (1980). Throughout this analysis, the responses of the 28XX officers were compared to those of all officers, using the Statistical Package for the Social Sciences' (SPSS's) FREQUENCIES routine (Nie, et al., 1975:181-201).

The first set of comparisons are of questions relating to career intent. Since the fiscal year 1978 and fiscal year 1979 retention rates given in Table II for engineers were lower than the retention rates for all support officers, one would anticipate that career intent would be lower for engineers as well. This anticipation is substantiated by the results shown in Table VI.

The rest of this analysis sought evidence indicating why the retention rates and career intent of engineers were lower than that of other officers. The Air Force Quality of Life Survey elicits responses indicating the degree of

TABLE VI
COMPARISON OF CAREER INTENT SURVEY RESPONSES

Which one of the following best describes your attitude toward making the Air Force a career?

	<u>28XX Officers</u>	<u>All Officers</u>
Definitely/most likely intend to make the AF a career	66%	70%
Undecided	23%	18%
Definitely/most likely do not intend to make the AF a career	11%	12%

How often do you think about quitting the Air Force?

	<u>28XX Officers</u>	<u>All Officers</u>
Never/Rarely	32%	33%
Sometimes	28%	40%
Often/Constantly	40%	27%

At the time you came on active duty in the Air Force, which one of the following best describes the attitude you had toward making the Air Force a career?

	<u>28XX Officers</u>	<u>All Officers</u>
Definitely/most likely intend to make the AF a career	49%	52%
Undecided	28%	29%
Definitely/most likely do not intend to make the AF a career	23%	19%

satisfaction with respect to nine different aspects of Air Force life. A question similar to the one shown in Figure 5 was included for each of the nine factors. To identify areas of different perceived levels of satisfaction, the average of the 28XX officers' responses was compared to the average of all officers' responses to each of the QOAFL factors. These comparisons are shown in Figure 6. This technique for comparing the mean responses is not exactly equivalent to an analysis of variance since the 28XX officer responses are included in the responses for all officers. However, since the total survey sample is considerably larger than the 28XX subsample, it is evident that Economic Standard is the only factor for which the mean of the 28XX responses is significantly¹ lower than the mean for all officers.

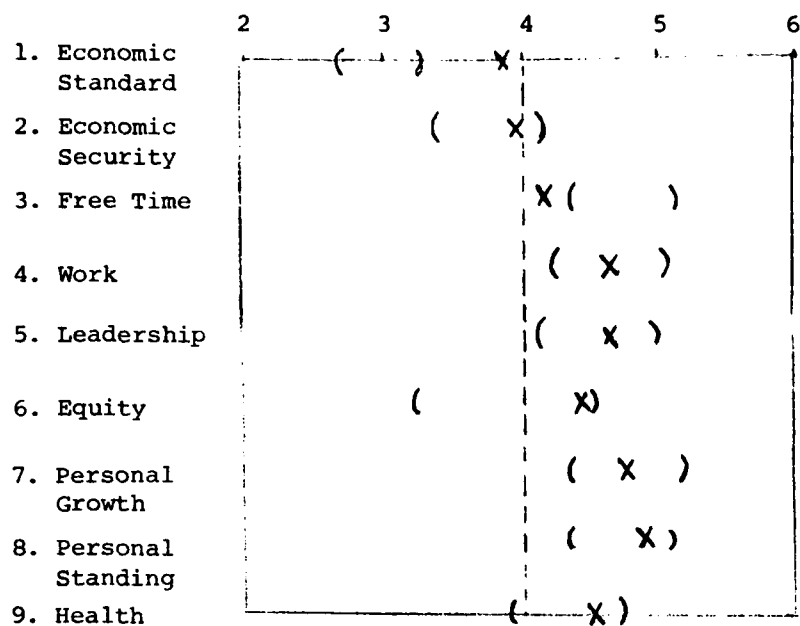
ECONOMIC STANDARD: Satisfaction of basic human needs such as food, shelter, clothing; the ability to maintain an acceptable standard of living.

20. To what degree are you satisfied with the ECONOMIC STANDARD aspects of your life: (Select one of the seven points on the satisfaction scale.)

A	B	C	D	E	F	G
Highly Dissatisfied			Neutral			Highly Satisfied

Fig. 5. Presentation of Typical QOAFL Question
(McNichols, et al., 1980:8)

¹"Significant" in this case is used to mean that the null hypothesis $N_E \geq N_A$ can be rejected at $\alpha = .05$ where N_A is the mean response for all officers and N_E is the mean response for all 28XX officers.



NOTE: () indicates the 95 percent confidence interval for the mean of the 28XX officers; X indicates the mean for all officers' responses.

Definitions

ECONOMIC STANDARD: Satisfaction of basic human needs such as food, shelter, clothing; the ability to maintain an acceptable standard of living.

ECONOMIC SECURITY: Guaranteed employment; retirement benefits; insurance protection for self and family.

FREE TIME: Amount, use, and scheduling of free time alone, or in voluntary associations with others; variety of activities engaged in.

WORK: Doing work that is personally meaningful and important; pride in your work; job satisfaction; recognition for my efforts and my accomplishments on the job.

LEADERSHIP/SUPERVISION: Has my interests and that of the Air Force at heart; keeps me informed; approachable and helpful rather than critical; good knowledge of the job.

EQUITY: Equal opportunity in the Air Force; a fair chance at promotion; an even break in my job/assignment selections.

Fig. 6. Comparison of Mean Quality of Air Force Life Factor Satisfaction Levels

PERSONAL GROWTH: To be able to develop individual capacities; education/training; making full use of my abilities; the chance to further my potential.

PERSONAL STANDING: To be treated with respect prestige; dignity; reputation; status.

HEALTH: Physical and mental well-being of self and dependents; having illnesses and ailments detected, diagnosed, treated and cured; quality and quantity of health care services provided.

Fig. 6--Continued

The responses to two other questions in the survey which are straightforwardly related to retention are compared in Tables VII and VIII. The substantially higher percentage of 28XX officers who cited pay and allowances as the one factor influencing them not to make the Air Force a career is particularly noteworthy.

And finally the questions displayed in Table IX focus upon the officers' attitudes relevant to the economic standard factor identified previously. In total, the results of this comparison of the responses of 28XX officers to all other officers, support the conclusion that 28XX officers have stronger feelings that they are inadequately compensated for their work.

In fact, these differences are surprisingly strong when compared to the lower rankings given of the importance of salary by previous studies as shown in Table IV. There are several potential explanations for this. One reason for the difference may be timing. With the widely held perception that in recent years military salaries have decreased in real terms while engineer salaries paid in the private sector have increased rapidly, the importance of salary in determining career decision, may have increased since the other surveys were administered.

Another possible explanation is that the survey responses to questions related to salary may have exhibited less variation and thus less explanatory power. That is to say, if all respondents are uniformly dissatisfied with

TABLE VII

COMPARISON OF PRIMARY NEGATIVE CAREER DECISION FACTORS

Select the one factor which TODAY would influence you the most NOT to make the Air Force a career.

	<u>All Officers</u>	<u>28XX Officers</u>
Pay and allowances*	22%	45%
Family separation	16	5
AF policies and procedures	6	5
My Air Force job	8	5
Little say in future assignments	7	6
Promotion system*	8	10
Insecurity of Air Force life	6	6
Promotion opportunity*	7	4
Leadership/supervision	5	3
Frequent PCS moves	4	1
Housing	1	1
Fringe benefits*	4	5
Air Force people	1	1
Some other factor	4	3
Nothing unfavorable	2	3
*Factors related to compensation	<u>41</u>	<u>64</u>

TABLE VIII

COMPARISON OF PRIMARY AFFIRMATIVE CAREER DECISION FACTORS

Select the one factor which TODAY would influence you the most to make the Air Force a career.

	<u>All Officers</u>	<u>28XX Officers</u>
Pay and allowances*	15%	9%
Training and education	6	11
Retirement*	14	13
Having a say in future assignments	8	1
Travel and new experiences	5	2
My Air Force job	23	28
Security of Air Force life	5	5
Promotion system*	9	10
Service to country	6	9
Fringe benefits*	1	0
AF leadership/supervision	2	2
AF policy & procedures	1	0
Housing	-	0
Some other factor	6	6
*Factors related to compensation	<u>39</u>	<u>32</u>

TABLE IX
COMPARISON OF RESPONSES ON MILITARY PAY

How do you think your military pay (including all allowances and fringe benefits) compares with pay in civilian employment for similar work?

	<u>28XX Officers</u>	<u>All Officers</u>
Military pay is far higher than civilian	0%	1%
Military pay is somewhat higher than civilian	0	4
Both about equal	5	8
Military pay is somewhat less than civilian	27	40
Military pay is far less than civilian	68	47

If I left the Air Force tomorrow, I think it would be very difficult to get a job in private industry with pay, benefits, duties, and responsibilities comparable with those of my present job.

	<u>28XX Officers</u>	<u>All Officers</u>
Strongly disagree	71%	36%
Disagree	23	39
Undecided	5	11
Agree	1	11
Strongly agree	0	3

In the future I believe my military income will provide me with an acceptable standard of living.

	<u>28XX Officers</u>	<u>All Officers</u>
Strongly disagree	35%	15%
Disagree/Slightly disagree	39	44
Neither agree or disagree	7	7
Slightly agree/Agree	18	31
Strongly agree	2	3

pay regardless of whether they plan to separate or not, the regression techniques such as those employed by Mosbach and Scanlan or Lewis cannot identify the influence of pay on career intent. On the other hand, the comparative analysis above rests on the assumption that satisfaction with any aspect of Air Force life is positively related to retention. It could be that although officers are dissatisfied with their salaries, their dissatisfaction has no substantial bearing on their career intent.

One last potential explanation of the different indications of the importance of salary for retention lies in the individual survey instruments. For example, both the Mosbach and Scanlan survey and Lewis' survey asked respondents to rate the desirability of "earning a high salary." Had the questions asked about the desirability of "earning a salary at least comparable to civilians performing similar work," the responses may have been considerably different.

In any event, there are many other compelling arguments

. . . that wages play a paramount role in either detracting from or contributing to motivation. . . . I would tend to disagree with anyone who would even remotely suggest that wages occupy only a minor role and are therefore deserving of nothing more than a passing reference. To the contrary, a wage system where problems or complaints (real or perceived) are present can offset and undo everything else that an organization or an individual manager may be attempting in the area of motivation. In short, the system for monetary reward of job performance is akin to the first stage of a rocket. If it fails, all else fails. Viewed another way there is

nothing better than a good foundation. If the foundation is sound and a little care is taken in building the rest of the structure, it will stand for a long time.

So it is with wages. If the compensation system is well conceived and well administered, it can go a long way toward enhancing and augmenting motivational efforts based on other factors. Conversely, effort in other directions can be substantially weakened and in some cases made completely ineffective because of a poor wage payment system.

It is interesting to note, however, that many of our more progressive companies are beginning to alter their strategy. Although they are not omitting reference to wages, they are placing increased emphasis on other job factors which hopefully will appeal to the candidate. These "other job factors" relate to the broader job climate which the employee will find. More specifically, emphasis is being placed on the opportunity to satisfy the social, psychological, and self-fulfillment needs. Accordingly, such things as challenge, achievement, JOB significance, freedom to work, etc., are being stressed. That employees respond to these types of motivators is confirmed by the numerous studies that have been carried out on labor turnover. Particularly among professional and semiprofessional people, it has been found that turnover is more frequently explained by the deficiencies in what have been previously labeled as motivational factors than dissatisfaction with wage.

For our purposes, however, the wage level issue has other significant aspects to it. If a man perceives that his wage level is too low in relation to the available market for his labor, he is likely to become dissatisfied. When this dissatisfaction appears, any number of things can happen. First, he may adjust his performance downward and put in only that amount of time and effort for which he thinks he is being compensated. Second, he may decide to reenter the labor market and thus seek an alternative source of employment which will not only pay more but, perhaps, also cure some of the other job deficiencies which bother him. The better qualified he is the more alternative sources of employment will present themselves and the more likely it is that eventually he will leave.

Finally, if for some reason he has decided he doesn't want to leave or that no interesting alternative sources of employment present themselves, he may adjust his performance downward as indicated earlier and also become one of those people who constantly find other things wrong in the environment. Enough of these people can have some serious long-range effects on the organization as well as the other employees [Scanlan: 450, 451].

Because these arguments and the results obtained from the Air Force Quality of Life Survey analysis indicate that compensation is one of the key determinants in 28XX officer career decisions, the remainder of the study was devoted to developing a methodology for assessing the cost effectiveness of various proposals related to special compensation for military engineers. The model designed to assist analysts in producing such assessments is described in the next chapter.

III. The System Dynamics Model

This chapter describes the system dynamics model designed to help policy makers evaluate proposals aimed at attracting and/or retaining additional development engineer officers. As discussed in Chapter II, such assessments are based on a comparison of manning levels, effectiveness indicators, and costs. The model described in this report provides a tool for making preliminary assessments of alternative policies and for determining what additional information is needed.

The next section of this chapter provides a description of the concept of the real development engineer officer personnel system used in formulating the model. Then a brief discussion of how the model should be evaluated is presented before proceeding to a detailed description of how each aspect of the model is designed to simulate the real 28XX officer personnel system.

In this chapter, the terms officer, development engineering officer and 28XX officer are all considered synonymous. In general, these terms refer only to the ranks from Second Lieutenant through Lieutenant Colonel. Although the focus of the study has been on the 28XX career field, many of the basic features of the model are applicable to any career field.

The model represents an attempt to simulate the real development engineer officer personnel system in a manner adequate to provide substantial assistance in formulating policies. The aspects of the real system represented in the model are described in the next section.

Abstract of the Development
Engineering Officer
Personnel System

The 28XX officer personnel structure is a complex and dynamic system effected by decisions made by a wide variety of managers as well as by individual perceptions of conditions in and out of the Air Force. To formulate the model, a structural concept of the actual 28XX officer personnel system was developed. This abstraction of the real system was illustrated by Figure 4 in Chapter I. In this conceptualization, all 28XX officers are aggregated into four different ranks: Lieutenants, Captains, Majors, and Lieutenant Colonels. Similarly, all flows into, out of or within the system are aggregated into one of five flows: voluntary separations, accessions, promotions, passovers, and transfers.

The levels of aggregation were judged to be those essential and adequate to consider in policy formulation. More detailed shredouts were considered and rejected. For example, officer levels could be expressed in an array indexed by rank, number of years in the Air Force, number of years as a 28XX officer, and number of years of prior

enlisted service. Although costs and experience levels would vary between these subgroups, it was assumed that such variance would not be significant; that is to say, each officer of the same rank can be viewed as costing the same amount and having the same capabilities on average. Given this assumption, the shredouts would have made the model much more complex with only marginal increases in accuracy. Similarly, the model could have specifically represented administrative discharges and deaths as separate outflows from the system. However, both discharges and deaths can be viewed as an insignificant part of the voluntary separations flow.

Two aspects of the real system not included in the model bear particular notice. First, the levels of personnel represented in the model do not include officers in transit or in school. This essentially assumes that the rate into these "pipeline" assignments is equal to the rate out. The second potentially significant aspect not included in the model is the outflow of officers resulting from Reductions in Force (RIFs). This study assumes that there will be no RIFs effecting 28XX officers for the timeframe included in analyses conducted with the model.

Based on this conceptualization of the real engineering officer system, a system dynamics model was constructed. The model is designed to provide two basic measures of effectiveness plotted over time. The first of these measures is the set of manning ratios between the

number of assigned personnel and the authorizations for each rank. The second effectiveness measure is an approximate indicator of the productive capacity associated with the projected levels of 28XX officers in each grade. This measure is estimated by the function discussed in Appendix D.

As indicated in Chapter I, the various rates of flow determine the levels which in turn determine the measures of effectiveness. These rates are assumed to respond to various elements of the environment. For example, the voluntary separations and accession rates are assumed to respond favorably to increases in the ratio of military to civilian salaries for engineers. These salaries are influenced within the model by pay policies, inflation, and the demand for engineers.

Viewpoint for Evaluating the Model's Design

The defense of any model rests primarily on the defense of the details of its design. This means the evidence and the arguments to justify not only the form of each equation but also the selection of system boundaries, system variables, and assumed system interactions between variables.

The importance of justifying model detail rests on a fundamental working assumption, the assumption that if all the necessary components are adequately described and properly interrelated, the model system cannot do other than behave as it should [Forrester, 1961:117].

When evaluating this model by analyzing the details of its design described in this chapter, readers should apply the standard of adequacy rather than that of accuracy. As complex as the model is, more precision could be achieved

by adding additional variables or disaggregating some variables currently in the model. However, the usefulness of such modifications should be assessed in light of the uncertainties involved in any projection of future conditions.

The model has been designed to enable users to assess the effects of many different possible future conditions in comparing specific policy alternatives.

As advisors, our objective is insensitivity as frequently as it is optimization: we seek to define systems that will work well under many widely divergent contingencies and even give some sort of reasonably satisfactory performance under a major misestimate of the future [Quade, 1977:15].

Many of the parameter estimates and representations of decision processes in this version of the model are only rough approximations of the "true" values and relationships. However, as Forrester (1961:101,171) indicates,

The common belief that we cannot quantify a decision rule because we do not know it with high accuracy is mixing two quite separate considerations. We can quantify regardless of accuracy. After that, we deal with the question of what is sufficient accuracy.

.
I feel that extensive data gathering and analysis should follow the demonstration of a need for more accuracy in a particular parameter. For many purposes values of parameters anywhere within the plausible range will produce approximately the same results.

The model presented in this report provides a tool for dealing with this question of sufficient accuracy. The question may have different answers in different situations depending upon the alternatives being considered. In each case, the model allows analysts to reach tentative conclusions based on initial estimates and then to assess the

results of varying the parameter estimates over a range of reasonable values. If the same alternative is selected regardless of the parameter values used in the model, then the research required to improve the estimate is not necessary.

The rest of this chapter describes in detail how the model simulates the real 28XX officer personnel system and calculates effectiveness indicators and cost estimates associated with the system. The computer program of the model and the remainder of this chapter are organized into ten main sections: one including the manpower levels, one for the productive capacity indicator, one for each of the five main personnel flows, two for military and civilian pay, and finally one for cost calculations. The equation forms and symbols used in this chapter are illustrated in the section on manpower levels for readers unfamiliar with System Dynamics terminology. The voluntary separations section includes a description of causal loop diagrams which are used to depict some of the underlying hypotheses of the model.

Section 1: Manpower Levels

Verbal Description. The most obvious measure of effectiveness of retention policies is the number of officers retained. One stated goal of managers concerned about the Air Force's engineer shortfall is to bring the total engineering officer manning up to 100 percent within five

years (Gaffney, 1980b). Therefore the system dynamics model focuses upon the numbers of officers in each of four different grade levels (Lieutenants through Lieutenant Colonels). In the System Dynamics language, these are called "levels" which are determined by the various flows into and out of each rank. As explained previously, these levels are represented in the model as the result of applying the voluntary separation rate, accession rate, promotion rate, and pass-over rate to the current levels specified by the input. These rates are assumed to vary in response to private sector demand and policy alternatives input to the model. Therefore, the rank levels are intended to reflect the dynamic behavior of the system in response to these influences.

One of the determinants of total 28XX manning is the number of rated supplement officers assigned to the career field. Over the past several years, the Air Force has reduced the rated supplement force as a whole, and the 28XX quota in particular, to compensate for a high attrition rate for pilots (Slay, 1979a). As of September 1980 there were 382 rated supplement officers in the 28XX career field. Even without an emergency requiring more rated officers in the cockpit, the decreasing trend is expected to continue until the end of fiscal year 1980. Then the number of 28XX rated supplement officers is expected to level out at about 322 officers (Snell, 1980). These projected rated supplement levels are provided as a direct input to the model.

The total of the 28XX officers in each rank is then computed by merely adding the number of rated supplement officers to the number of 28XX support officers determined dynamically by the model.

Of course, the total numbers of officers in each rank have more meaning to management when compared to the requirements for each rank. As discussed in Chapter I, the requirements for 28XX officers are assumed to be validly indicated by the approved authorizations. The current authorization levels are provided as inputs to the model as the expected average percentage growth in authorizations. This percentage growth is applied to the current authorization in each rank in a linear fashion over time. The rank levels and authorizations are used in the model to compute the percentage manning for each grade and for the entire 28XX career area. These manning levels can be provided as output to indicate the response to policy alternatives incorporated in the representations of flows discussed later in this chapter.

The manpower section of the model will be used to illustrate the terminology common to the mathematical model descriptions of all other aspects of the system. This terminology which is common to all System Dynamics studies is described in more detail by Forrester (1961:67-92) and Pugh (1976).

Flow Diagrams. The drawing in Figure 7, called a flow diagram, depicts how the rates and levels associated with Lieutenants, Captains, and total manpower are represented in the model. This figure represents, in the standard format, part of the concept of the development engineer officer system illustrated earlier in Figure 4. The state of the system at any given time can be expressed by the values of the various levels which are represented by rectangles in Figure 7.

The flow of personnel is represented by the double-lined arrows while information flows are depicted by dotted lines. The "valves" on the personnel flow lines represent the rate equations which govern the flow. Whenever information about the current value of one variable is used in computing another variable, there is an information flow line drawn from the first variable's symbol to the second variable's symbol. For example, as shown in Figure 7, the promotion rate to Captain depends upon the number of Lieutenants in the array element SUPORT(2).

Many of the information flow lines to the rate symbols are excluded from this drawing to avoid the additional complication. The flow diagram for the entire model is provided in Appendix B.

The cloud-like figures indicate the flows which are either coming into or leaving the subsystem represented in the model. The circles represent auxiliary variables which are calculated based on the levels or other auxiliary

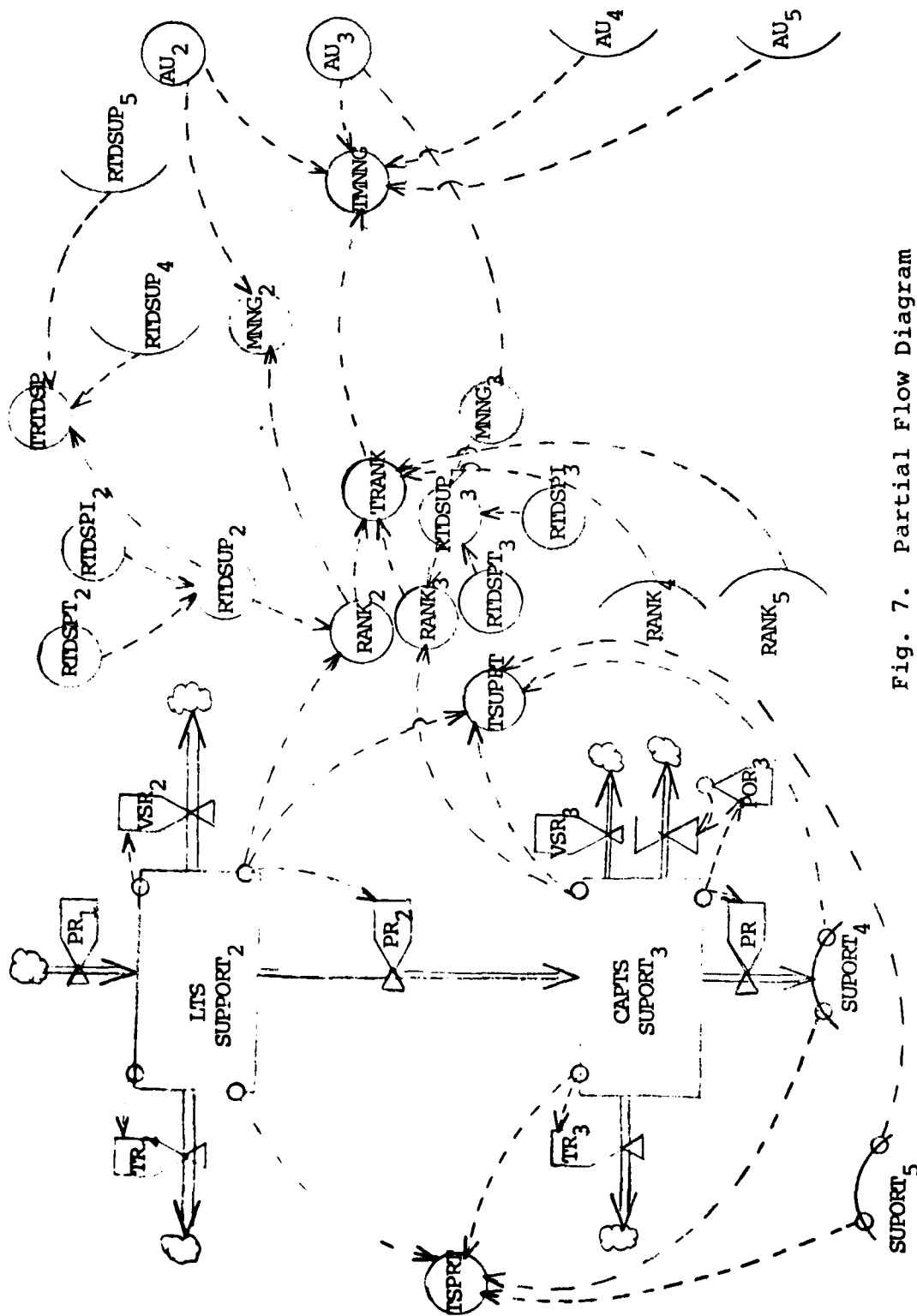


Fig. 7. Partial Flow Diagram

variables. These auxiliary variables also can be used in the equations for rates. Finally, the half circles represent variables which are included in another flow diagram. By referencing the semi-circles, the flow diagram in Figure 7 can be connected to the complete flow diagram in Appendix B.

Dynamo Equations. DYNAMO equations are labeled according to the type of variable being computed: "L" for level, "A" for auxiliary, "R" for rates, "C" for constants, "T" for tables (vectors of constants) and N for the initial value of any variable. A "X" means the equation on the previous line is being continued.

"For" variables are defined to index the contents of arrays. Whenever one of these variables is in an equation, the DYNAMO compiler merely generates a single equation for each index value. So the use of For variables just saves the analyst from having to write out several extra equations. The For variables defined in this model are of two types. Those beginning with "I" represent grade levels from 1 for Second Lieutenants up to 6 for Colonels. Except for salaries, variables related to Second Lieutenants and First Lieutenants are combined in the second element of the appropriate arrays. So an "I" index of 2 means all Lieutenants unless indicated otherwise. A "J" indicates those For variables representating different years within one or more grades. In either case, the range of the For variables is indicated by the remainder of its name. For example,

an equation with variables indexed by the For variable "I3T05" would apply to grades 03 to 05 (Captains through Lieutenant Colonels).

DYNAMO computes the values of all variables in a sequence of time intervals specified by a "DT" constant which is defined in the model.

The first quantities to be calculated at the instant K are all the levels. These depend on their own previous value (at time J), on auxiliaries computed at time J . . . and on rates computed for the interval JK. As all quantities for J and JK have already been calculated, there is no difficulty carrying out the level computations. See Figure [8].

Next, auxiliaries, automatically ordered by DYNAMO, are calculated for the instant K from levels at K and other auxiliaries calculated earlier for K.

Finally, rates are calculated for the interval KL from levels and auxiliaries at time K. Like the levels, the rates do not provide any ordering problems. (In the rare instance when a rate appears in an auxiliary or rate equation, the rate from the JK interval is used, avoiding creation of any ordering problems.)

Once the rates have been calculated, the present TIME is advanced DT time units; all quantities that have been calculated for TIME K are now considered to be the values at TIME J; and rates computed for the interval KL are now treated as though they are JK values. The computation cycle then starts over again with the level computations [Pugh, 1976:4-5].

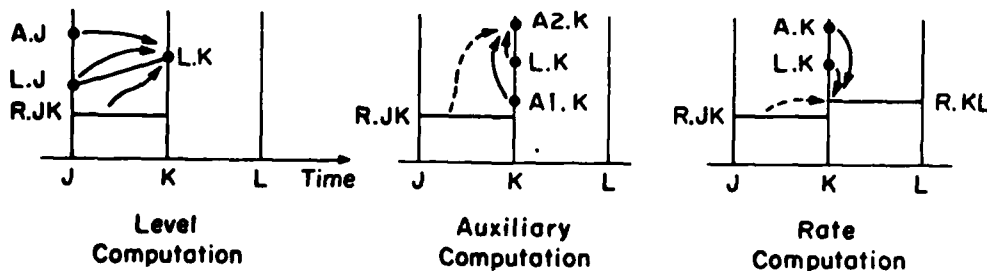


Fig. 8. Sequence of Computation [Pugh, 1976:5]

Mathematical Model. The use of many of the DYNAMO concepts explained above are illustrated in the manpower structure of the model shown in Figure 9. Equation 1-14 of this figure is the core of the entire model. It shows the number of support officers assigned at time "K" to the 28XX career field, indexed from Lieutenant through Lieutenant Colonel, to be the value for the beginning of the preceding interval plus the change computed by multiplying the rates for the preceding interval by the length of the interval "DT." The rate variables (indicated by the "JK" time subscripts) with negative coefficients represent outflows while those with positive coefficients represent in flows. These various flows are defined in rate equations which are discussed in subsequent sections of this chapter.

The "A" equations define the values of auxiliary variables with FORTRAN-like algebraic statements and special purpose DYNAMO functions. The SUM function in equations 1-0, 1-3, and 1-6 computes the total of all elements of the array given to it.

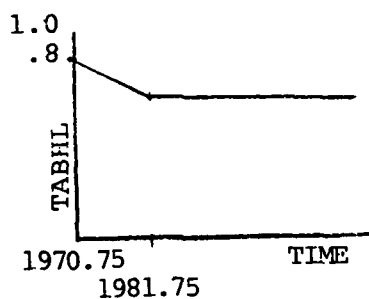
Another type of DYNAMO function, the table function, enables users to represent arbitrary relationships between variables by entering table values of the dependent variable corresponding to equally spaced values of the independent variable. For example, the TABHL function in equation 1-8 takes time (which is set to start at 1980.75 for September 30, 1980) as the independent variable and provides

NOTE SECTION 1: MANPOWER LEVELS

```

A THNG.K=TRANK.K/SUM(AU.K) 1-0
A MNNG.K(1)=0 1-1
A MNNG.K(I2T05)=RANK.K(I2T05)/AU.K(I2T05) 1-2
A TRANK.K=SUM(RANK.K) 1-3
A RANK.K(1)=0 1-4
A RANK.K(I2T05)=RTDSUP.K(I2T05)+SUPORT.K(I2T05) 1-5
A TRTDSUP.K=SUM(RTDSUP.K) 1-6
A RTDSUP.K(1)=0 1-7
A RTDSUP.K(I2T05)=RTDSPI(I2T05-1)+
X TABHL(RTDSPT,TIME.K,1980.75,1981.75,1) 1-8

```



```

T RTDSPI=0/184/84/114 1-9
T RTDSPT=1/.84 1-10
A TSUPRT.K=SUM(SUPORT.K) 1-11
L SUPORT.K(1)=SUPORT.J(1)+DT*TR.JK(1) 1-12
N SUPORT(1)=0 1-13
L SUPORT.K(I2T05)=SUPORT.J(I2T05)+DT*(TR.JK(I2T05)-
X VSR.JK(I2T05)+PR.JK(I2T05-1)-POR.JK(I2T05)-PR.JK(I2T05)) 1-14

```

Fig. 9. Model Structure Representing Manpower Levels

N SUPRT(I2T05)=SUPRTI(I2T05-1) 1-15
 T SUPRTI=1011/1220/715/306 1-16
 A AU.K(I1T05)=AUTHI(I1T05)+(1+RAMP(AUGROW,START)) 1-17
 T AUTHI=0/533/2362/935/563 1-18
 C AUGROW=0 1-19

TMNNG	TOTAL MANNING (PERCENT OF TOTAL AUTHORIZED) 1-8	
	STRENGTH	
MNNG(I)	MANNING IN GRADE I (PERCENT OF AUTHORIZED	1-
TRANK	TOTAL ASSIGNED (OFFICERS)	1-3
RANK(I)	ASSIGNED IN RANK I (OFFICERS)	1-5
TRTDSUP	TOTAL RATED SUPPLEMENT (OFFICERS)	1-6
RTDSUP(I)	RATED SUPPLEMENT IN RANK I (OFFICERS)	1-8
RTDSPI(I)	INITIAL RATED SUPPLEMENT IN RANK I	1-9
	(OFFICERS)	
TSUPRT	TOTAL SUPPORT (NON-RATED) (OFFICERS)	1-11
SUPRT(I)	SUPPORT IN RANK I (OFFICERS)	1-13
SUPRTI(I)	INITIAL SUPPORT IN RANK I (OFFICERS)	1-16
TR(I)	NET TRANSFER RATE (INTO+, OUT-) FOR	9-0/1
	RANK I (OFFICERS/YR)	
VSR(I)	VOLUNTARY SEPARATION RATE FROM RANK I	3-1
	(OFFICERS/YR)	
PR(1)	ACCESSION RATE ("PROMOTION TO 2LT")	6-0
	(OFFICERS/YR)	
PR(I)	PROMOTION RATE FROM RANK I (FOR I=2 TO 5)	7-0,
	(OFFICERS/YR)	
POR (I)	PASSED OVER SEPARATION RATE (OFFICERS/YR)	8-0/5
AU(I)	AUTHORIZATIONS IN RANK I (BILLETS)	1-17
AUTHI(I)	INITIAL AUTHORIZATIONS IN RANK I (BILLETS)	1-18
AUGROW	GROWTH RATE OF AUTHORIZATIONS (BILLETS/YR)	1-19

Fig. 9--Continued

a value by interpolating between the values given in the table RTDSPT (equation 1-10) corresponding to the end points (1980.75 and 1981.75) and interval size provided in the TABHL function. In other words, the TABHL function multiplies RTDSPI by the fractional value which is related to TIME by the graph also shown in Figure 9. By changing the increments in the TABHL function and the RTDSPT values, the model can incorporate any projection of the 28XX rated supplement.

The only other DYNAMO function used in the manpower section is the RAMP function in equation 1-17. This function returns a value equal to

$$\text{AUGROW} * (\text{TIME.K} - \text{START}).$$

Its value over time actually forms a ramp of slope AUGROW beginning at

$$\text{TIME.K} = \text{START}.$$

The $\text{AUGROW} = 0$ equation represents no growth in the Air Force's 28XX authorizations. The value of AUGROW can be reset for any run, so that total authorizations increase proportionately each year.

This completes the discussion of the manpower section of the model. The next section describes how the manning levels of the RANK array (equation 1-5) are used to calculate the approximate indicator of productive capacity.

Section 2: Productive Capacity

As indicated in Chapters I and II, Air Force decision makers must be concerned about the overall technological capacity provided by a development engineer officer force not just the total number of engineers. Accordingly, an indicator of productive capacity was incorporated in the model. The productive capacity function included in the model was developed by interviewing an experienced 28XX manager as described in Appendix D.

The productive capacity function is represented as shown in Figure 10 as an auxiliary variable which depends upon the numbers of Lieutenants (L), Captains (C), and Field Grade Officers (F) assigned to the "average" Air Force organization. As explained in Appendix D, this "average" organization was defined as an establishment with 100 28XX authorizations structured in the same proportion as the entire Air Force's 28XX authorized grade structure. Assuming all the 28XX officers are equitably assigned to each "average" organization, the capacity of any one "average" organization is representative of the total productive capacity associated with the Air Force's 28XX officer force. Since the productive capacity function was developed for an establishment with 100 28XX authorizations, the total number of 28XX officers in each rank is "resized" as shown in equations 2-1 to 2-3.

NOTE SECTION 2: PRODUCTIVE CAPACITY

A $PROD.K = A0 + A1 * F.K + A2 * F.K * C.K + A3 * (F.K ** 2) +$
X $A4 * (L.K ** 2) * (C.K ** 2) +$
X $A5 * (C.K ** 2) + A6 * C.K +$
X $A7 * L.K * (C.K ** 2)$ 2-0
A $L.K = RANK.K(2) * RESIZE.K$ 2-1
A $C.K = RANK.K(3) * RESIZE.K$ 2-2
A $F.K = (RANK.K(4) + RANK.K(5)) * RESIZE.K$ 2-3
A $RESIZE.K = 100 / SUM(AU.K)$ 2-4
C $A0 = -.153.51029, A1 = 12.91364, A2 = .03101887$ 2-5
C $A3 = -.20186564, A4 = .61566605E-5, A5 = -.41040323E-2$ 2-6
C $A6 = 0, A7 = 0$ 2-7

PROD	PRODUCTIVE CAPACITY (PERCENT OF COMPLETE MISSION)	2-0
L	LTS IN "AVERAGE" ORGANIZATION (OFFICERS)	2-1
C	CAPTS IN "AVERAGE" ORGANIZATION (OFFICERS)	2-2
F	FIELD GRADE OFFICERS IN "AVERAGE" ORGANIZATION (OFFICERS)	2-3
RANK(I)	ASSIGNED IN RANK I (OFFICERS)	1-5
RESIZE	"FAIR SHARE" OF TOTAL OFFICERS ASSIGNED FOR EACH "AVERAGE" ORGANIZATION (PERCENT)	2-4

Fig. 10. Model Structure Representing Productive Capacity

It is important to note that if the authorizations are assumed to change over time (i.e., if the growth of authorizations (AUGROW) $\neq 0$, then the productive capacity for two different points in time is not directly comparable. That is to say, if

$$AU(t_1) \neq AU(t_2)$$

then $PROD(t_1)$ and $PROD(t_2)$ are not directly comparable except in terms of the "percentage"¹ of their respective required capacities.

The form of the productive capacity function and the estimates for the coefficients A0 through A5 were derived from a regression fit of the interviewee's scores of different rank structures as discussed in Appendix D. The C.K and L.K*CK**2 terms of equation 2-0 were not in the final estimate of the productive capacity function. However, as discussed in Appendix D, these last two terms could appear in the estimate of the function if the scores elicited from the decision makers were changed slightly. Therefore, these constants were included to enable users to perform sensitivity analyses including other potential forms of the productive capacity functions.

This completes the discussion of all the effectiveness measures provided by the model. The next six sections describe the various rates which determine the levels of

¹More accurately, these are just ordinal measures of the decision maker's preferences on separate scales of 0 to 100.

non-rated 28XX officers represented by the SUPORT array which formed the basis of all the effectiveness calculations. The first flow to be described is the voluntary separation rates.

Section 3: Voluntary Separation Rates

Two options are available in the model for representing the voluntary separation of 28XX officers from the Air Force. The simple option is included to allow users the ability to investigate other aspects of the system without being concerned with the complexities involved in the more complicated dynamic representation.

The structure of the simpler option is shown in Figure 11, equation 3-5'. This option is selected by setting the constant

$$\text{VSROPT}=0 \qquad (3-4)$$

The more complex option is used if $\text{VSROPT} \neq 0$.

The critical assumption of this equation is that, except for Lieutenants, a set percentage (called the Voluntary Separation Rate Factor) of the officers in any grade will separate from the Air Force each year. For Lieutenants, it is assumed that a fixed percentage of the number completing their initial obligation, will separate each year. This rate is assumed to include the negligible percentage²

²For the period 1 April 1979 to 30 March 1980, only 4 out of 798 28XX officers in the first 3-year groups were lost (AFMPC, 1980a).

NOTE SECTION 3: VOLUNTARY SEPARATIONS

R VSR.KL(1)=0
R VSR.KL(2)=VSRF.K(2)*OUT2.K 3-1
R VSR.KL(I3T05)=VSRF.K(I3T05)*SUPORT(I3T05) 3-2
A VSRF.K(I1T05)=SWITCH(VSRF0(I1T05),VSRF1.K(I1T05),VSR0PT) 3-3
C VSR0PT=1 3-4

NOTE INITIAL VSR OPT

T VSRF0=0/.34/.07/.06/.18 3-5'

NOTE ALTERNATE VSR OPTION

A VSRF1.K(1)=0 3-4.1
A VSRF1.K(2)=TABHL(ELAST2,PAYNDX.K(2),.6,1.3,.05) 3-5
T ELAST2=.99/.95/.88/.8/.7/.6/.5/.4/.34/.27/.21/.15/.09/.04/.01
A VSRF1.K(3)=TABXT(ELAST3,PAYNDX.K(3),.85,1.15,.05) 3-7
T ELAST3=.20/.14/.10/.07/.04/.02/.019 3-8

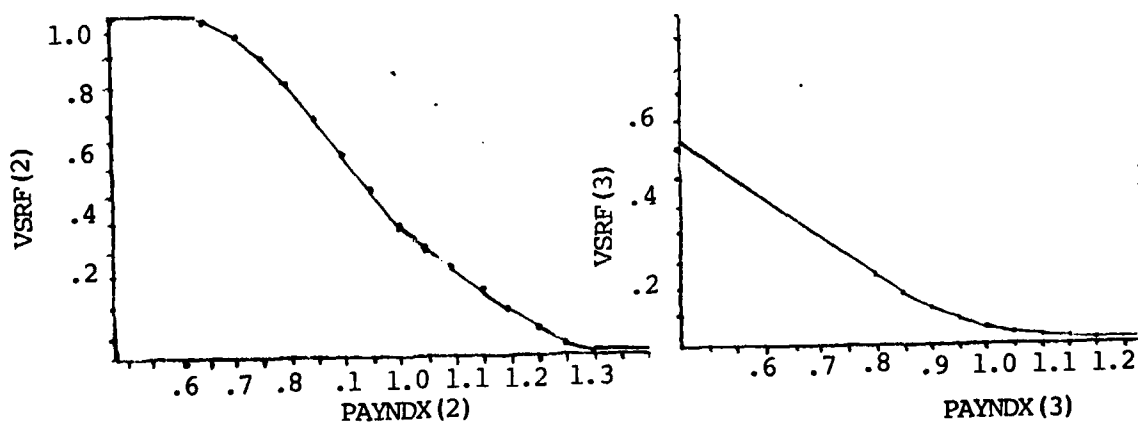
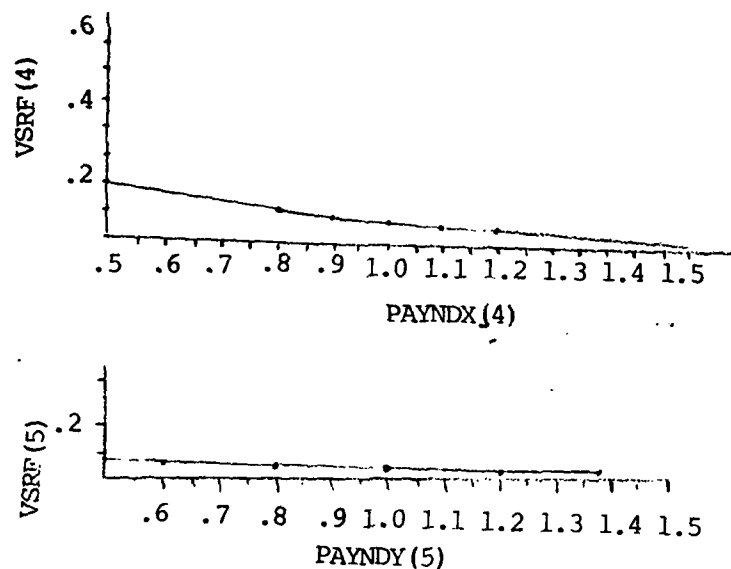


Fig. 11. Model Structure Representing Voluntary Separations



A VSRF1.K(4)=TABXT(ELAST4,PAYNDX.K(4),.8,1.2,.1) 3-9
T ELAST4=.09/.07/.06/.055/.049 3-10
A VSRF1.K(5)=TABXT(ELAST5,PAYNDX.K(5),.6,1.4,.2) 3-11
T ELAST5=.23/.20/.18/.16/.15 3-12

A PAYNDX.K(I1T05)=RATIO.K(I1T05)/RATIO(I1T05) 3-13
A RATIO.K(I1T05)=PVFMP.K(I1T05)/PVFCP.K(I1T05) 3-14
N RATIO(I1T05)=RATIO(I1T05) 3-15

VSRF(I)	ASSUMED STATIC VOLUNTARY SEPARATION RATE FACTOR (PERCENT/YR)	3-5
VSR(I)	VOLUNTARY SEPARATION RATE FROM RANK I (OFFICERS/YR)	3-1
VSR0PT	VOLUNTARY SEPARATION RATE OPTION (0 FOR VSR=VSR0 OR 1 FOR VSR=VSR1)	3-2
VSRF	VOLUNTARY SEPARATION RATE FRACTION (PERCENT/YR)	3-5/11
SUPORT(I)	SUPPORT IN RANK I (OFFICERS)	1-13
PAYNDX	PAY INDEX (DIMENSIONLESS)	3-13
RATIO	RATIO OF PVFMP TO PVFCP (DIMENSIONLESS)	3-14
PVFMP(I)	PRESENT VALUE OF FUTURE MILITARY PAY EXPECTED BY THE AVERAGE OFFICER OF RANK I (\$)	4-1
PVFCP(I)	PRESENT VALUE OF FUTURE CIVILIAN PAY EXPECTED BY THE AVERAGE OFFICER OF RANK I (\$)	5-1

Fig. 11--Continued

who separate before completing their commitment. The calculation of the number of Lieutenants completing their initial obligation each year is described later under the promotion rate section.

Using this option the voluntary separation rate factors (VSRFs) can be varied for different runs of the model if different proposals are expected to yield different attrition rate. However, with any given run, the percentage of officers in grade I separating remains fixed at VSRF(I) throughout the time period being projected. Analysts using this option should be careful to interpret the VSRFs as the assumed average value for the projected period.

The more complicated option for representing voluntary separations is provided as a tool to assess the dynamic behavior of the voluntary separation rates. In this option the percentage of officers separating from each grade is assumed to fluctuate in response to a fluctuating demand for engineers in the private sector. The extent of the voluntary separation factor's response is determined by the compensation provided by the Air Force. The effort required to develop this more complex structure was deemed necessary because

. . . year-to-year variations in [retention] rates can and should be exploited to the military's advantage. When the private-sector labor market is uninviting and [retention] rates are high, the experienced cadre would grow beyond the minimum requirements, providing a hedge against a less congenial future [Foch, 1977].

In this option, the voluntary separation rate factors are applied in the same fashion as in the simpler option, but the factors themselves are assumed to vary over time in response to the changing perceptions of military versus civilian compensation.

Causal Loop Diagrams. To introduce the underlying hypotheses of the more complex structures, this section and subsequent sections will use a graphic technique called causal loop diagramming. The causal loop diagram for the voluntary separation rate is presented in Figure 12. The algebraic signs and arrows between variables of this diagram indicate the hypothesized relationships.

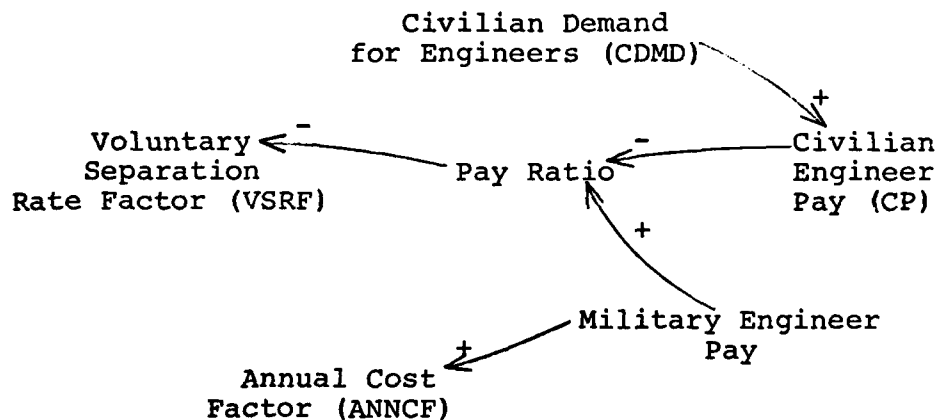


Fig. 12. Hypothesized Determinants of Voluntary Separation Rates Causal Loop Diagram

When a change in one variable produces a change in the same direction in a second variable the relationship is defined as positive. When a change in the second variable runs in the opposite direction, the relationship is defined as negative. The variables are linked

together to form the feedback loops of the system. The polarity of a loop is determined by assuming all else remains constant and tracing the results of an arbitrary change around the loop: (1) Reinforcement of the change indicates a positive feedback loop; (2) Opposition to the change indicates a negative feedback loop.

Causal-loop diagramming simplifies the transformation of verbal description into feedback structure. Such diagramming also readily reveals the loop structure of complex models to people unfamiliar with flow diagrams or DYNAMO notation. Although useful as communication tools, causal-loop diagrams cannot substitute for detailed flow diagrams which must first be constructed before simulation analysis can proceed further [Goodman, 1974:11-12].

As discussed in Chapter I, an increase in the demand for engineers usually results in an increase in engineers' salaries higher than the increases in salaries of other occupations. Thus there is a positive relationship between demand and civilian engineer pay as indicated in the causal loop diagram. The pay ratio is defined as the present value of the future military pay an engineer expects if he stays in the Air Force divided by the present value of future civilian pay he would expect if he got out. Obviously, as civilian pay increases, this ratio would decrease (thus the negative relationship between civilian pay and the pay ratio). Conversely, as military pay increases the pay ratio increases. On the other hand, the cost to the Air Force for each officer increase with increasing military salaries. And finally, as discussed in Chapter II, there is a negative relationship between the pay ratio and the voluntary separation rate factor.

The variable PAYNDX (see equation 3-13 of Figure 11) is merely an index of the pay ratio defined such that the initial value is equal to 1.0. The general shape of the hypothesized relationship between the voluntary separation rate factor (VSRF) and PAYNDX for any grade is depicted in Figure 13. In general, as the pay index increases, the VSRF is expected to decrease but at a decreasing rate, asymptotically approaching a number greater than zero since deaths, discharges and such are included in the VSRF. Conversely, as the pay index decreases the VSRF increases at an increasing rate until it tapers off at close to the 100 percent loss rate.

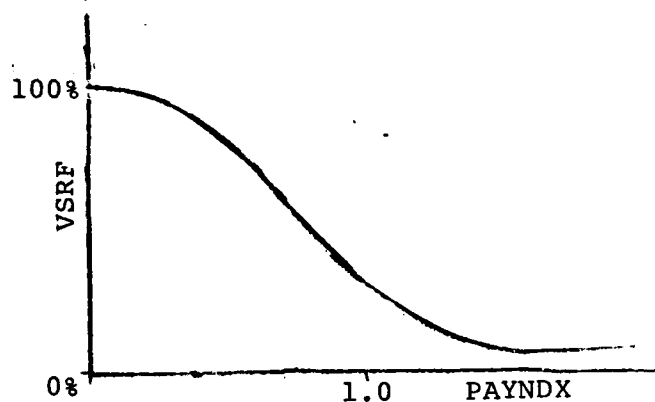


Fig. 13. Hypothesized Relationship Between the Indexed Ratio of Military to Civilian Pay and the Voluntary Separation Rate Factor

Even approximate estimates of the precise shape of these curves for each grade were not discovered in the literature review conducted for this study. Yet even before the model was completely implemented, it became

evident that the system is quite sensitive to variations in the table values representing this curve for each grade.

The initial table values for the assumed responses for each grade were estimated using data from two sources. First the VSRF associated with the PAYNDX value of 1.0 was estimated from an analysis of actual losses of 28XX officers by year group (AFMPC, 1980a). The average rate for each grade was then adjusted to account for the separations due to passovers for promotion to Major and for the "pipeline" (transients and in school) officers who were assumed to exhibit a negligible attrition rate.

The slope at PAYNDX=1.0 was estimated by adapting the mean elasticity for each grade used by Gaffney (1980a:3).³ These elasticities are shown in Table X. From this beginning, table values were assigned to approximate the shape of Figure 13.

Obviously, this approach achieves only a rough approximation of the true relationship between the pay ratio and the voluntary separation rate. But at least this provides a basis for sensitivity analysis to determine the extent that a more precise estimation would be useful.

In conclusion, the voluntary separation rate is represented in the model as being determined by the ratio

³Gaffney used the elasticity for retention; these elasticities were converted to attrition elasticities by

$$\xi_A = 1 - \frac{1 - (1 - \text{VSRF}(I))}{\text{VSRF}(I)} (1 + \xi_R/100)$$

where ξ_A is the attrition elasticity and the ξ_R is the retention elasticity.

TABLE X
ATTRITION ELASTICITIES^a FOR INITIAL RUNS

Rank	Elasticity
End of Initial Obligation (EOB)	-3.8
Captains	-9.96
Majors	- .94
Lieutenant Colonels	- .47

^aAttrition elasticity as used herein is defined as the percentage change in the VSRF per small percentage change from the PAYNDX. For example, with an attrition elasticity of -2 and a PAYNDX value of 1.001 would yield a VSRF .2 percent lower than the initial VSRF. Note these elasticities are not readily comparable since the VSRF at EOB is considerably higher than it is for Majors.

of expected future military pay to expected future civilian pay. The next two sections describe how these two variables are calculated by the model.

Section 4: Military Pay

The causal loop diagram in Figure 14 depicts the hypotheses underlying the representation of military pay in the model. These hypotheses will be discussed along with the presentation of the detailed structure. The military pay section of the program is depicted in Figure 15.

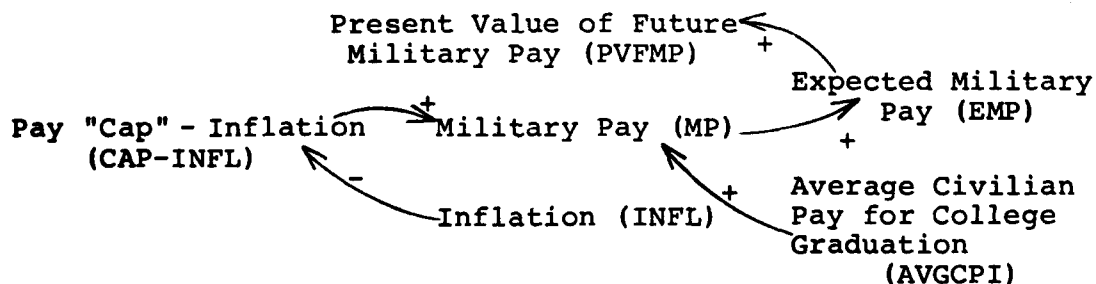


Fig. 14. Hypothesized Determinants of Military Pay
Causal Loop Diagram

NOTE SECTION 4: MILITARY PAY

```

A PWFMP,K(I1T05)=SCLPRD(EMP,K(I1T05),1,6,D,1) 4-1
A EMP,K(1,J1T02)=MP,K(1) 4-2
A EMP,K(1,J3T04)=MP,K(2) 4-3
A EMP,K(1,J5T06)=0 4-4
A EMP,K(2,J1T06)=MP,K(3) 4-5
A EMP,K(3,J1T04)=MP,K(3) 4-6
A EMP,K(3,J5T06)=PD(4)*MP,K(4)+(1-PD(4))*MP,K(3) 4-7
A EMP,K(4,J1T03)=MP,K(4) 4-8
A EMP,K(4,J4T06)=PD(5)*MP,K(5)+(1-PD(5))*MP,K(4) 4-9
A EMP,K(5,J1T03)=MP,K(5) 4-10
A EMP,K(5,J4T06)=PD(6)*MP,K(6)+(1-PD(6))*MP,K(5) 4-11
L MP,K(I1T06)=MP,J(I1T05)-DT*MPINCR,K(I1T06) 4-12
N MP(I1T06)=MPI(I1T06) 4-13
T MPI=14701/19711/24059/29689/35847/43961 4-14
R MPINCR,K(I1T06)=MPINCR,K(I1T06)*MP,K(I1T06) 4-15
A MPINCR,K(I1T06)=MIN(COMP,K(I1T06),CAP,K-INFL,K) 4-16
A COMP,K(I1T06)=DELAY3(RAISE,K(I1T06),*PLAG) 4-17
A RAISE,K(I1T06)=(FRONT,K(I1T06)*CP,K(I1T06)-
X MP,K(I1T06))/MP,K(I1T06) 4-18
A FRONT,K(I1T06)=(AVGCP,I(I1T06)/CPI(I1T06))/CPNEX,K 4-19
T AVGCP,I=17937/20571/29416/36366/47057/50170 4-20
C *PLAG=1 4-21
A CAP,K=TABXT(CAPBL,INFL,K,3,2,1) 4-22
T CAPBL=.2/.07/.15 4-23

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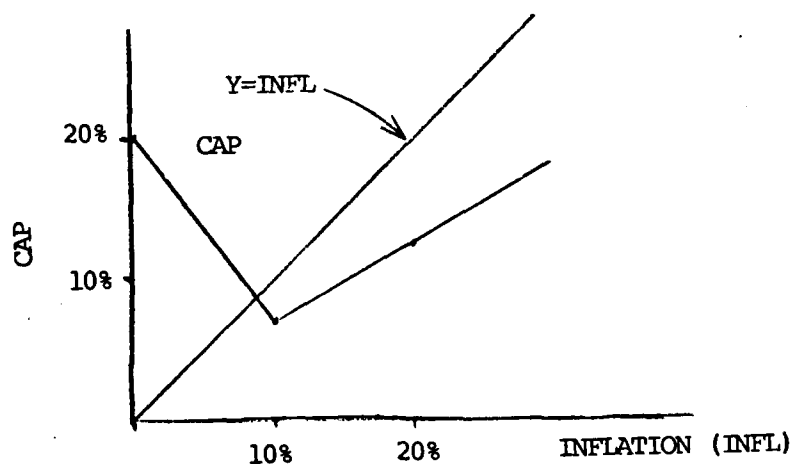


Fig. 15. Model Structure Representing Military Pay

$A \text{ INFL} = A \text{ INFL} + H \text{ GHT} * \sin(2 * \pi * (TIME - START) / CYCLE + \pi * \pi) +$
 $X \text{ RAMP}(SLOPE, START) + RANDOM * NOISE()$ 4-24
 $C \text{ AINFL} = .06$ 4-25
 $C \text{ H GHT} = .06, CYCLE = 4, \pi = 3.1416, \pi = .5$ 4-26
 $C \text{ SLOPE} = 0$ 4-27
 $C \text{ RANDOM} = 4$ 4-28

$N \text{ DIJIT06} = 1 / (1 + PDSCNT) + J \text{ IT06}$ 4-29
 $C \text{ PDSCNT} = .1$ 4-30

PUMF(I)	PRESENT VALUE OF FUTURE MILITARY PAY EX- PECTED BY THE AVERAGE OFFICER OF RANK I (\$)	4-1
EMP(I,J)	EXPECTED MILITARY PAY FOR AVERAGE OFFICER IN RANK 0-4 FOR THE JTH YEAR IN THE FUTURE (\$)	4-2/11
D(J)	DISCOUNT FACTOR FOR J YEARS IN THE FUTURE (DIMENSIONLESS)	4-29
MP(I)	MILITARY PAY FOR RANK I (\$)	4-12
PO(I)	PROMOTION OPPORTUNITY TO GRADE I (PER CENTAGE)	7-6
PDSCNT	PERCEIVED DISCOUNT INTEREST RATE (DIMEN- SIONLESS)	4-30
MPINCR(I)	MILITARY PAY INCREASE RATE (\$/YR)	4-15
MPI(I)	INITIAL MILITARY PAY (REGULAR MILITARY COMPENSATION) FOR RANK I (\$)	4-14
MPINCF(I)	MILITARY PAY INCREASE FRACTION (PERCENT)	4-16
COMP	DELAYED MILITARY PAY INCREASE TO ACHIEVE "COMPARABILITY" IN RANK I (PERCENT)	4-17
RAISE(I)	MILITARY PAY INCREASE TO ACHIEVE "COMPARA- BILITY" IN RANK I (PERCENT)	4-18
PRCNT	PERCENTAGE OF CP REQUIRED BY "COMPARABILITY" POLICY FOR RANK I (PERCENT)	4-19
AVCCPI(I)	AVERAGE CIVILIAN PAY OF ALL PROFESSIONS FOR POSITIONS COMPARABLE TO RANK I (\$)	4-20
MPLAC	DELAY IN INCREASING MILITARY PAY (YRS)	4-21
CAP	MILITARY PAY CAP (PERCENT)	4-22
INFL	INFLATION (PERCENT)	4-24
AINFL	AVERAGE INFLATION RATE (PERCENT)	4-25
HGHT	HEIGHT OF AMPLITUDE IF SINE WAVE	4-26
CYCLE	LENGTH OF PERIOD OF SINE WAVE	4-26
PT	POINT OF INITIAL INFLATION ON SINE WAVE	4-26
SLOPE	LONG TERM INCREASE IN INFLATION (DIMENSION-	4-27
RANDOM	COEFFICIENT OF RANDOM COMPONENT OF INFL (DIMENSIONLESS)	4-28

Fig. 15--Continued

In a study of Navy pilot attrition, Kleinman (1979) assumed that officers considering separating from military service compare the present value of military compensation over the next six years to the present value of compensation expected if they separate. Since Kleinman's study was successful in estimating an econometric model of voluntary separation, this assumption was adopted for the System Dynamics model. For potential engineer officer candidates, the comparison timeframe was assumed to be four years, the normal initial obligation.

For each grade (I) the present value of expected future military pay (see equation 4-1) is the scalar product (computed by DYNAMO's SCLPRD function) of $EMP(I,*)$, the vector containing the expected military pay for each year of the comparison timeframe, and D, the vector of discount factors. The vectors of expected military pay for each grade is stored in a row of the 6 x 6 array $EMP(I1TO6, J1TO6)$. The expected military pay is computed for the average officer in each grade assuming: (1) the average Lieutenant spends two years as a Second Lieutenant and two years as a First Lieutenant; (2) the average Captain has four years to reach the "primary zone" at which time he perceives his probability of being promoted to be $PO(4) = .9$; (3) similarly, the average Major has three years to the primary zone for Lieutenant Colonel selection and the average Lieutenant Colonel has three years to the primary zone for promotion to Colonel. It is further assumed that these

officers' perceptions are based upon the salary in effect as of the time of potential separation (usually separation decisions are made in advance but pay raise recommendations are also announced in advance).

The initial military salaries are provided as an input to the model in the table MPI of equation 4-14. The values in this table represent the fiscal year 1980 average Regular Military Compensation⁴ by pay grade (Assistant Director, Compensation, 1979). From this base the military pay vector (MP) depends upon the cumulative effect of the real increases or decreases applied to it. The military pay vector at any time represents the estimated military pay in current dollars. The real percentage increase or decrease is the minimum (determined by the MIN function in equation 4-16) of COMP, the (delayed) raise needed to reach "comparability" and CAP.K-INFL.K. Thus the system strives to maintain "comparability" within constraints imposed by inflation and the government's reaction to it.

One of the basic tenants of the All Volunteer Force concept was the government's commitment to maintain the "comparability" of military salaries. Of course, this policy begs the question who is comparable to whom? From

⁴"Regular Military Compensation is the sum of Basic Pay, Quarters and Subsistence Allowances plus the tax advantage that accrues because the Quarters and Subsistence allowances are not subject to federal income tax [Assistant Director, Compensation, 1979]."

1973 until 1979 military wage increases were linked with civil service pay increases which were determined in part by the average salaries paid to private sector employees with comparable responsibilities and qualification requirements. These average salaries are estimated annually by the National Survey of Professional, Administrative, Technical and Clerical Pay (Bureau of Labor Statistics, 1979b). Thus the "comparability" policy called for all officers to receive Regular Military Compensation equal to the average for all college graduate employees with comparable positions.

The current policy which provides essentially the same compensation for all non-rated officers, is represented in the model by the PRCNT variable defined in equation 4-19. Since

$$CPNDX.K(I) = CP.K(I) / CPI(I)$$

(from equation 5-12, in the next section),

where, CP.K = civilian engineers' pay at instant K

CPI = initial civilian engineers' pay

and

$$\begin{aligned} PRCNT.K(I) &= (AVGCPI(I) / CPI(I)) / CPNDX.K & (4-19) \\ &= (AVGCPI(I) / CPI(I)) * (CPI(I) / CP.K(I)) \\ &= AVGCPI(I) / CP.K(I) \end{aligned}$$

so

$$\begin{aligned} RAISE.K(I) &= (PRCNT.K(I) * CP.K(I) - MP.K(I)) / MP.K(I) & (4-18) \\ &= (AVGCPI(I) - MP.K(I)) / MP.K(I) \end{aligned}$$

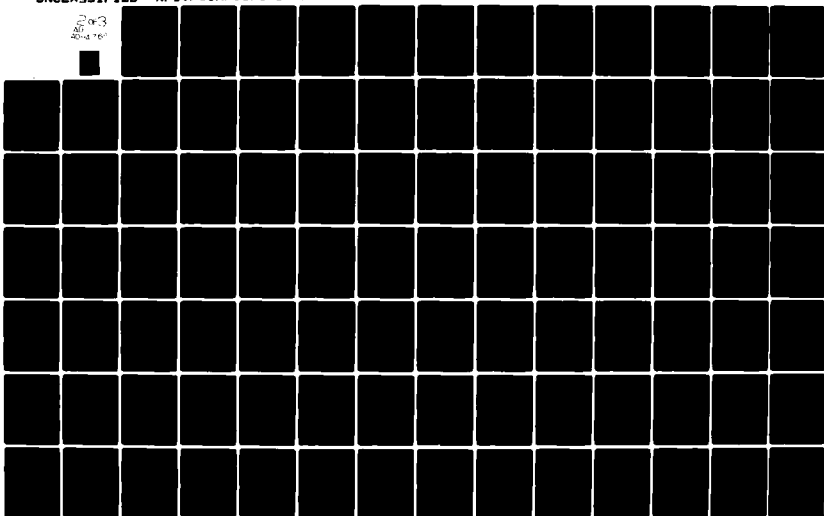
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AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCH00--ETC F/G 15/5
A SYSTEM DYNAMICS MODEL FOR ASSESSING THE COST-EFFECTIVENESS OF--ETC(U)
DEC 80 K L WILLIAMS
AFIT/60R/05/80D-7

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In words then, the pay raise is computed to achieve comparability with the constant AVGCPI (Average Civilian Pay) for all college graduates even though it is expressed as a percentage of the civilian engineers' pay. The PRCNT variable was defined in this roundabout fashion to allow users to specify alternative pay policies in terms of the percentage of civilian engineer salaries. For example

$$T \text{ PRCNT} = 1/1/1/1/1/1$$

would provide for full comparability for each grade of military engineer with their civilian engineer counterparts.

Average civilian engineer salaries are up to 20 percent⁵ higher than the average for all college graduates. So even if the current "comparability" policy were implemented for all Air Force officers with no constraints, the engineering officers would receive less compensation than engineers in comparable private sector positions.⁶

But the "comparability" policy only determines how much officers "should" be paid. Whether the raise to reach comparability can be afforded requires a political judgement

⁵The average for all college graduates was approximated based on the Bureau of Labor Statistics' Survey (1979) and publicized civil service pay recommendations.

⁶Of course, some cohort group must be established. If compensation for all officer engineers were comparable to the average civilian engineer's pay, then Air Force petroleum engineers would still receive less than their specific civilian counterparts.

by the U.S. Administration and Congress. This political determination is represented in the model by the CAP variable (equation 4-22). Whenever the real raise to achieve comparability is higher than the "pay cap" minus inflation, the cap-inflation amount is approved. Otherwise, the full raise for comparability is approved.

The sole determinant of the CAP variable as represented in the model is inflation. The nature of this hypothesized relationship is reflected in the graph in Figure 15. When inflation is high, the government tries to reduce government spending and to set an example of restraint in salary increases. When inflation is low such pressures are hypothesized to be not as severe so the pay cap is permitted to be reasonably high, up to a maximum of 20 percent as assumed by the input reflected in Figure 15 (any other assumed table values could be entered of course).

The particular representation of inflation shown in equations 4-24 through 4-28 was designed to achieve a random exogeneous input which produced results reasonably similar to the actual inflation rates since the 1950s. These actual annual inflation rates from 1950 to 1977 are shown in Figure 16. The model structure uses DYNAMO's uniform $[-\frac{1}{2}, \frac{1}{2}]$ random number function NOISE to generate random deviations around a pattern specified by the user in equations 4-25 through 4-28. The sine wave portion of equation 4-24 is included to represent the autocorrelated

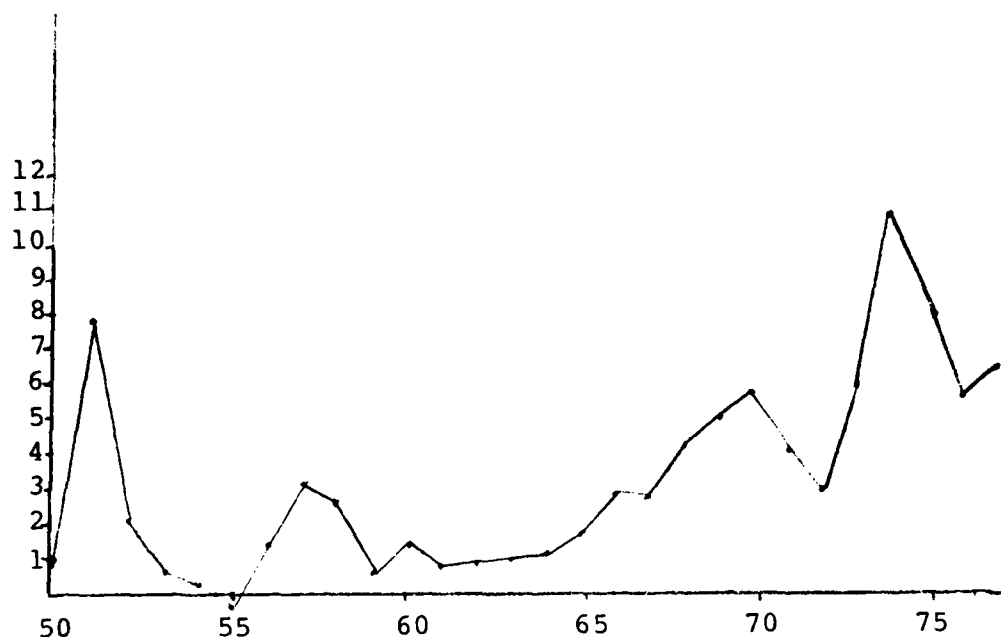


Fig. 16. Annual Inflation Rates 1950-1977
(Bureau of Labor Statistics, 1979:397)

behavior exhibited by historical inflation data.⁷ The RAMP function is included in equation 4-24 to allow users to specify a long-term growth in the inflation rate if a steady increase in inflation is anticipated, say, for an entire decade. The representation of inflation resulting from one set of parameter specifications and a given sequence of random numbers are shown in Figure 17. Any of the constants input by the value settings of line 4-28 can be changed to provide a random exogeneous input with behavior of interest to the user.

⁷The actual annual inflation rates for 1961 through 1977 have a mean $\approx 4.3\%$ and an autocorrelation coefficient for the first lag of .79.

INFL=1

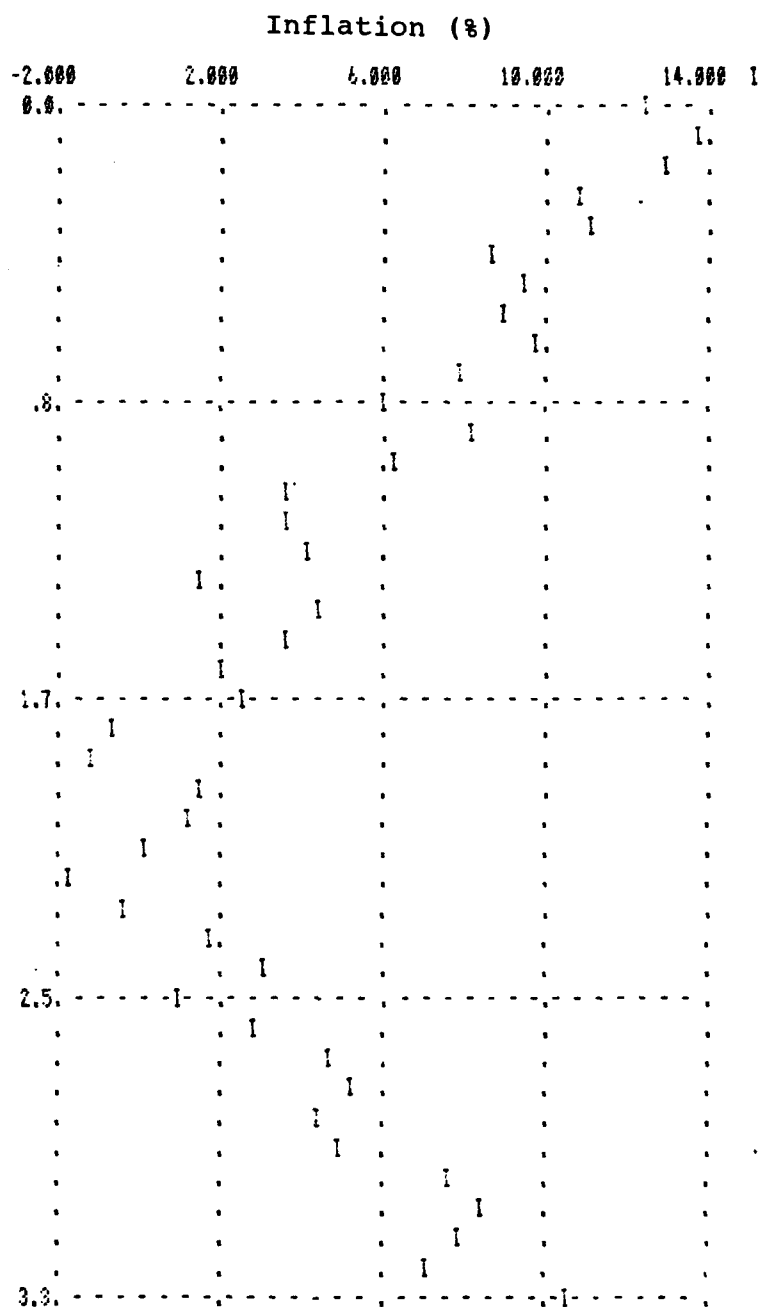


Fig. 17. One Series of Inflation Rates Randomly Generated by the Model

Summarizing the representation of military pay, the present value of future military pay is calculated based on the pay variable representing Regular Military Compensation for each officer grade. The Regular Military Compensation is viewed as being determined by efforts to achieve comparability with average civilian salaries for positions comparable to each officer grade. The efforts to achieve "comparability" are hampered by the government's response to inflation.

The next section describes the representation of civilian pay.

Section 5: Civilian Pay

As shown in Figure 18, the present value of expected future civilian engineer pay (PVFCP) is computed exactly like the PVFMP discussed in the last section. The civilian pay vector (CP) is designed to represent the salary which engineers in the private sector receive for positions comparable to the six military ranks Second Lieutenant through Colonel. Note that calculating the ECP array in exactly the same manner as EMP implies that officer engineers perceive the opportunity for promotions in the private sector to be approximately the same as in the military. What evidence uncovered in the literature review pertaining to this assumption, indicates that officers perceive the opportunity to be greater in the private sector (see Table A-IV, Appendix A). This may bias the ratio in favor

NOTE SECTION 5: CIVILIAN PAY

```

A PVFCP.K(I1T05)=SCLPRD(ECP.K(I1T05,*),1,6,D,1) 5-1
A ECP.K(1,J1T02)=CP.K(1) 5-2
A ECP.K(1,J3T04)=CP.K(2) 5-3
A ECP.K(1,J5T06)=0 5-4
A ECP.K(2,J1T06)=CP.K(3) 5-5
A ECP.K(3,J1T04)=CP.K(3) 5-6
A ECP.K(3,J5T06)=P0(4)*CP.K(4)+(1-P0(4))*CP.K(3) 5-7
A ECP.K(4,J1T03)=CP.K(4) 5-8
A ECP.K(4,J4T06)=P0(5)*CP.K(5)+(1-P0(5))*CP.K(4) 5-9
A ECP.K(5,J1T03)=CP.K(5) 5-10
A ECP.K(5,J4T06)=P0(5)*CP.K(5)+(1-P0(6))*CP.K(5) 5-11
A CP.K(I1T06)=CPNDX.K*CPI(I1T06) 5-12
N CPI(I1T06)=CPI(I1T06) 5-13
T CPI=21428/26014/31146/37235/45195/50079 5-14
L CPNDX.K=CPNDX.J+DT*RRCPR.JK 5-15
N CPNDX=1 5-15
R RRCPR.KL=(B0+B1*CDMD.K+NORMRN(0,0.0005))*CPNDX.K 5-17
C B0=-.01178743 5-18
C B1=.00011433 5-19
A CDMD.K=100*AMPL*SIN(2*PI*(TIME-START)/CYCL+POINT*PI)+
X RAMP(GROWTH,START)+NORMRN(0,ERRSD) 5-20
C AMPL=70,CYCL=5,POINT=.5,GROWTH=0 5-21
C ERRSD=4 5-22

```

Fig. 18. Model Structure Representing Civilian Engineer Pay

PVFCP(I)	PRESENT VALUE OF FUTURE CIVILIAN PAY EXPECTED BY THE AVERAGE OFFICER OF RANK I (\$)	5-1
ECF(I,J)	EXPECTED CIVILIAN PAY FOR AVERAGE OFFICER OF RANK I FOR THE JTH YEAR INTO THE FUTURE(\$)	5-2/11
CP(I)	CIVILIAN PAY FOR AN ENGINEER IN A POSITION COMPARABLE TO RANK I (\$)	5-12
CPI(I)	INITIAL CIVILIAN PAY FOR ENGINEERS IN A POSITION COMPARABLE TO RANK I (\$)	5-14
PO(I)	PROMOTION OPPORTUNITY TO GRADE I (PER CENTAGE)	7-6
D(J)	DISCOUNT FACTOR FOR J YEARS IN THE FUTURE (DIMENSIONLESS)	4-29
CPNDX	CP INDEXED WITH CPI=1 (DIMENSIONLESS)	5-15
RRCPR	REAL RELATIVE RATE OF CHANGE IN CPNDX (DIMENSIONLESS)	5-17
CDMD	INDEX OF CIVILIAN DEMAND FOR ENGINEERS (DIMENSIONLESS)	5-20
AMPL	AMPLITUDE OF SINE WAVE FOR CDMD (DIMENSIONLESS)	5-21
CYCL	CYCLE LENGTH (PERIOD OF SINE WAVE) FOR CDMD (DIMENSIONLESS)	5-21
POINT	POINT OF INITIAL DEMAND ON SINE WAVE FROM 0 - 2 (RADIAN)	5-21
GROWTH	LONG TERM GROWTH RATE FOR CDMD (INDEX VALUE/YR)	5-21
ERRSD	STANDARD DEVIATION OF THE ERROR FOR THE NORMAL RANDOM INPUT TO CDMD (DIMENSIONLESS)	5-22

Fig. 18--Continued

of higher values than actually perceived but this effect is assumed to be insignificant, especially since the ratio is always related to the initial pay ratio in determining the voluntary separation rate factor.

Real increases in the civilian pay array are determined in the model by the demand for engineers. The increases in engineering salaries relative to all other salaries included in the Bureau of Labor Statistics salary survey (1979) were related to the demand for engineers as shown in Figure 19. The measure of engineer demand is the Deutsch, Shea and Evans Index of High Technology Recruitment. The relationship between these two variables is represented in the model by the simple linear regression line shown in the figure. Obviously, the increases are not explained entirely by demand, thus a normal random residual is added to the estimate by using DYNAMO's NORMRN function as shown in equation 5-17 of Figure 18.

Figure 20 shows the historical values of the Deutsch, Shea, and Evans index of High Technology, Recruitment. This index is computed each month from the number and lineage of recruitment advertising directed to engineers and scientists in major newspapers and technical journals (D,S,&E, 1979). Figure 21 shows a projection based on the current representation of civilian demand for engineers as a sine wave exogeneous input. The RAMP function is included in equation 5-20 to allow users to specify a constant growth of the demand for engineers.

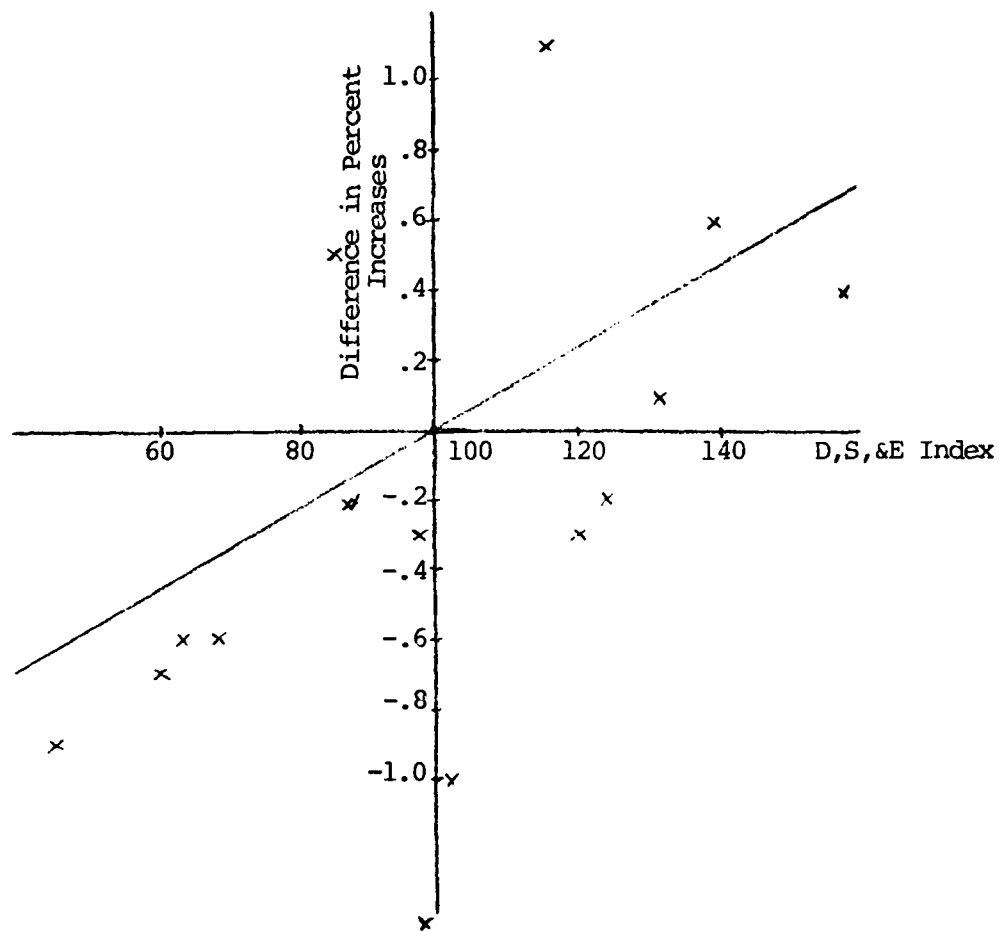


Fig. 19. Engineer Salary Increases Relative to Other Occupations Related to the Deutsch, Shea, and Evans, High Technology Recruitment Index (Bureau of Labor Statistics, 1979:3; and D,S,&E, 1979)

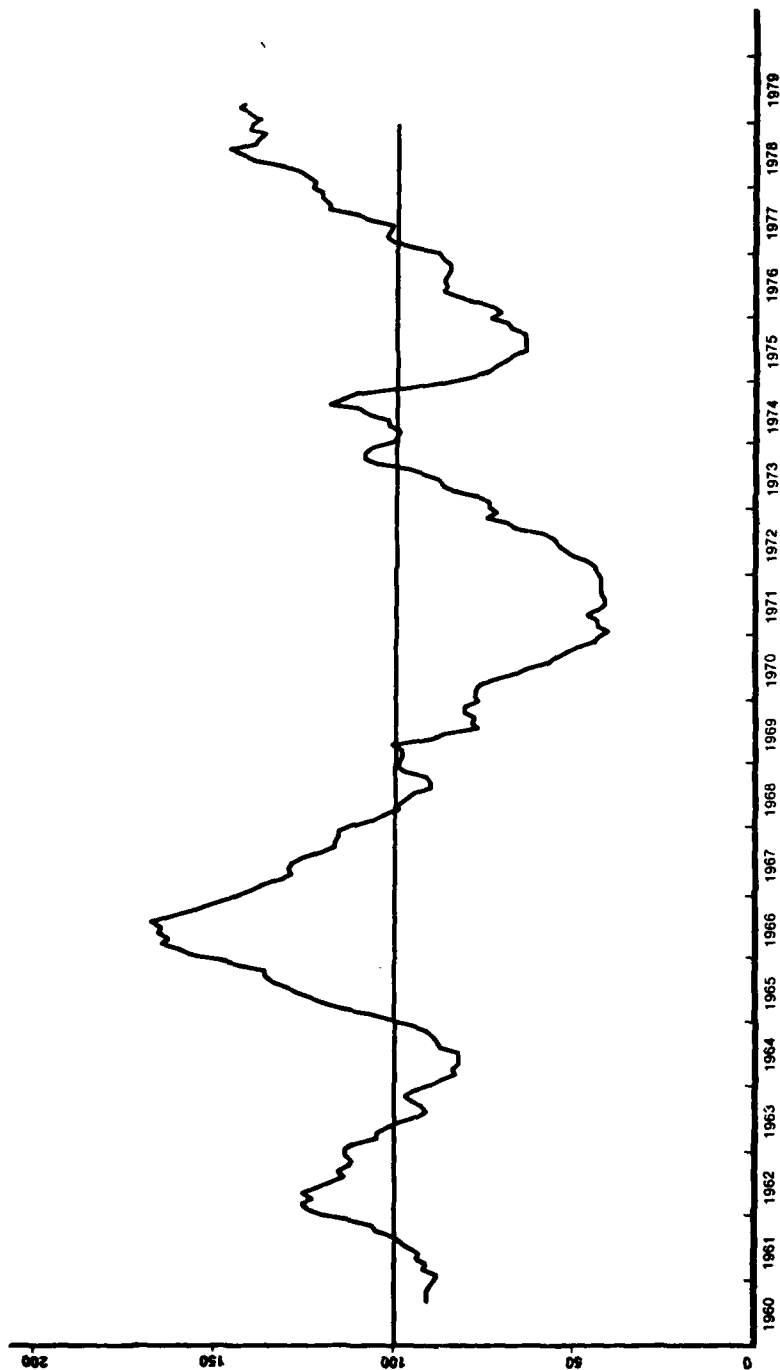


Fig. 20. Deutsch, Shea and Evans, Inc. High Technology Recruitment Index (1961=100; seasonally adjusted) Monthly Data: 1961-1979 (D,S&E, 1979)

CEMD-0

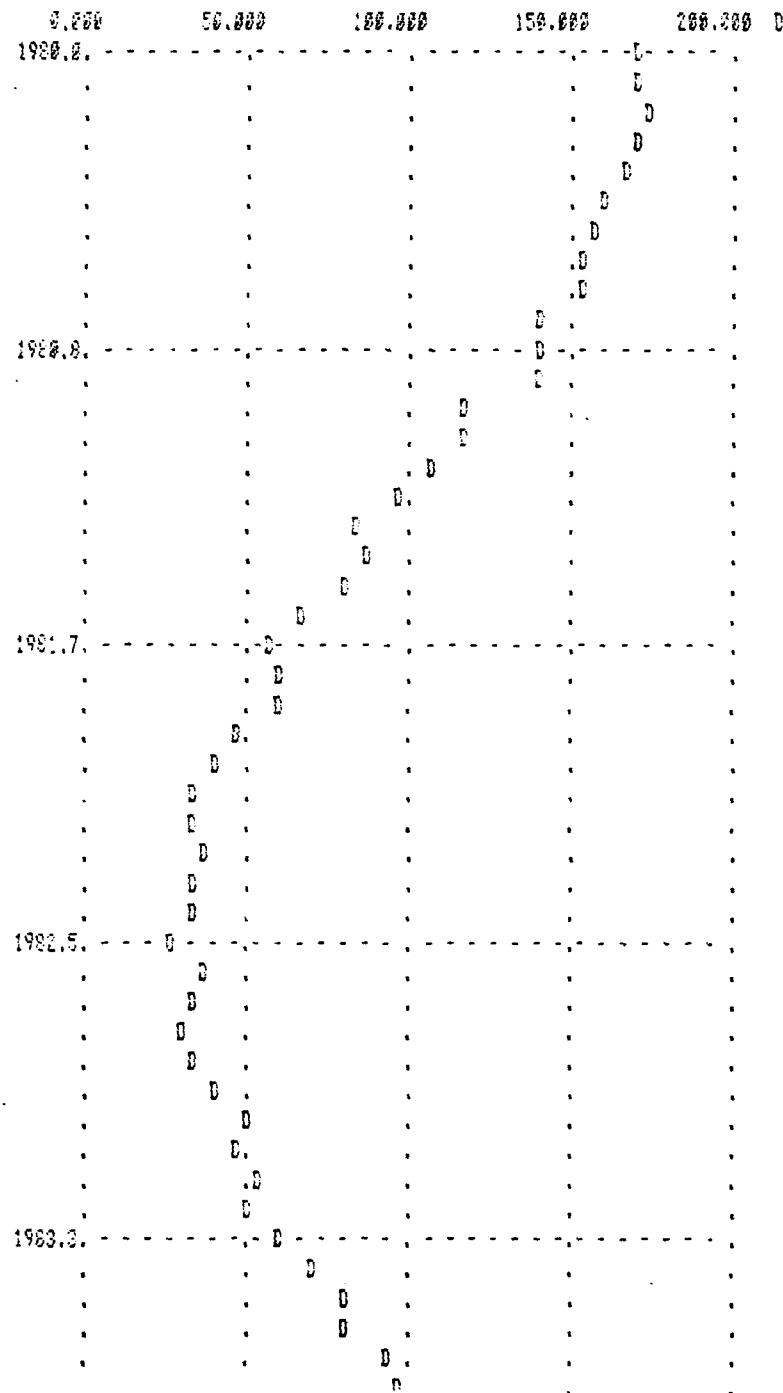


Fig. 21. Sample Projection of Demand for Engineers

Reviewing the civilian pay structure, the model uses an exogeneous input for civilian demand for engineers to determine the real increase (or decrease) in the civilian pay index which is multiplied by the initial civilian engineer salaries to determine the expected future engineer salaries. These civilian engineer salaries are compared to military salaries by officers in the Air Force in deciding whether or not to separate and by individuals deciding whether or not to enter the Air Force. This later process is described in the next section.

Section 6: Accession Rates

Like the voluntary separation rate structure, the structure for the accession rate has two options, one extremely simple and the other comparatively complex. In the current version of the model, the first option is entirely represented by the single equation

$$ACSNR0.K = 300 \cdot 6^{-2}$$

This equation was provided to allow users to assess the effects of a constant input or of fluctuating accession rates determined by an exogenous input in place of the constant value. As with the simple VSR option it allows users to separately identify the dynamic behavior of the system imposed by other elements of the model.

The causal loop diagram for the hypotheses associated with the accession rate is depicted in Figure 22.

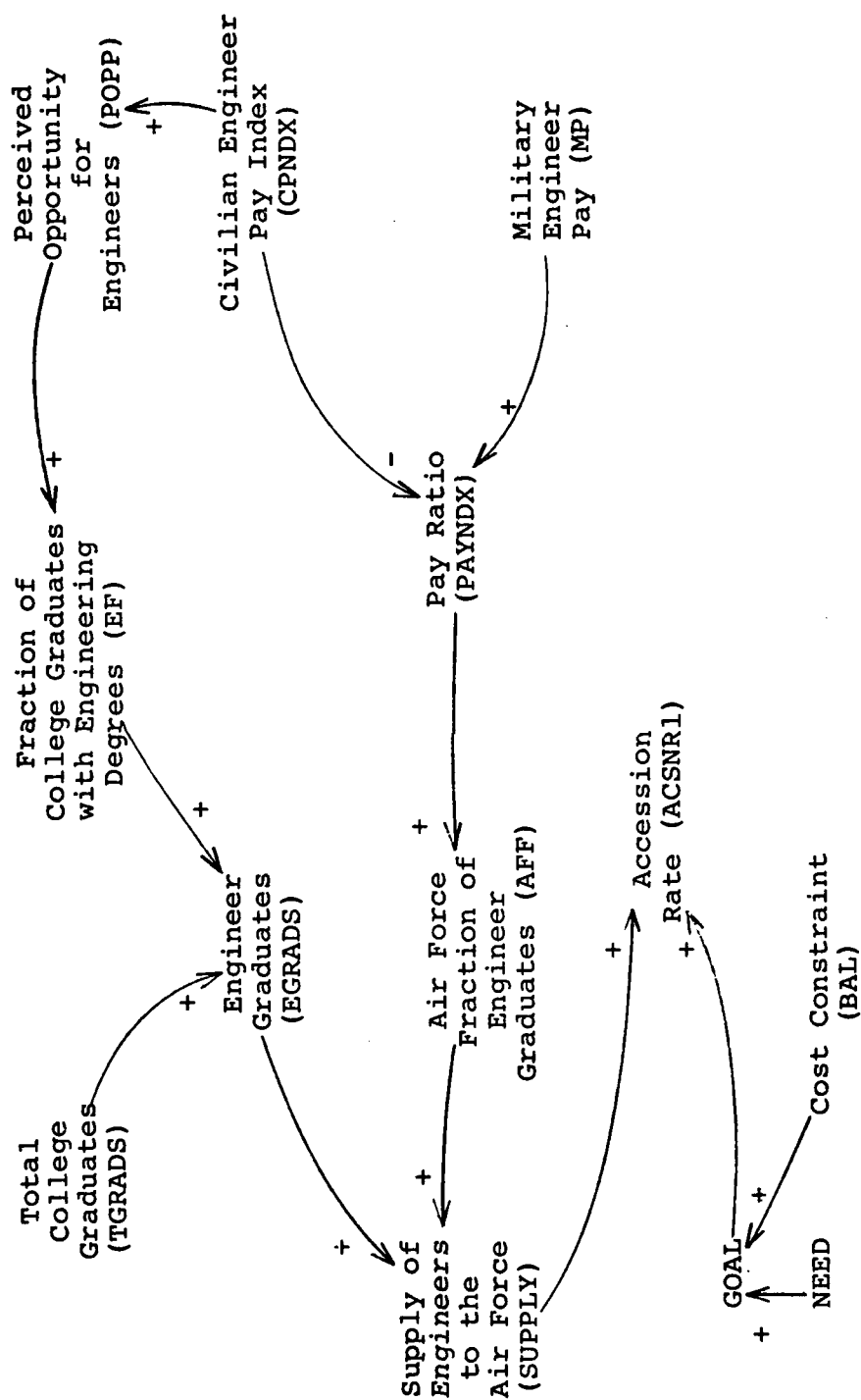


Fig. 22. Hypothesized Determinants of Accessions Causal Loop Diagram

The detailed structure is shown in Figure 23. In this representation, the accession rate is viewed as being the lower of (1) the supply of engineer graduates willing to join the Air Force, and (2) the goal established for recruiting 28XX officers. Note this does not preclude recruiting engineer graduates for placement in other career areas but the accession rate includes only those engineers joining the 28XX career field. The recruiting goal for 28XX officers is requested by the Air Force Manpower and Personnel Center's "Palace Vector" Team Chief who calculates the number of Second Lieutenants required to fill all vacancies in the entire career field and replace the expected losses due to attrition or promotion out of the system. The Palace Vector office estimates next year's losses by averaging the past year's attrition rates (Mackey, 1980). This moving average of losses is simulated in the model by the SMOOTH function in equation 6-7.

The balance variable BAL is an artificial variable included in the model so users can impose a cost constraint. This enables decision makers to compare alternatives since

. . . in general, it is not possible to choose between two alternatives (which have different costs and different levels of effectiveness). Usually, either a required effectiveness must be specified and then cost minimized for that effectiveness, or a required cost must be specified and the effectiveness maximized [Attaway, 1977:56-57].

BAL is calculated in the model as the difference between the cumulative costs and the constraint imposed by the annual budget (ANBDGT) constant provided by the user.

NOTE SECTION 6: ACCESSIONS

R PR.KL(1)=SWITCH(ACSNR0.K,ACSNR1.K,ACSNOP) 6-0
C ACSNOP=1 6-1

NOTE INITIAL ACCESSION OPTION

A ACSNR0.K=300 6-2'

NOTE ALTERNATE ACCESSION OPTION

A ACSNR1.K=MIN(GOAL.K,SUPPLY.K) 6-2
A GOAL.K=FIFGE(NEED.K,0,BAL,0) 6-3
A NEED.K=MAX(SUM(AU.K)-SUM(RANK.K)+SUM(LOSS.K),0) 6-4
N NEED=1000 6-4.5
A LOSS.K(I1T04)=SMOOTH(VSR.JK(I1T04)+POR.JK(I1T04),1) 6-6
A LOSS.K(5)=SMOOTH(VSR.JK(5)+PR.JK(5),1) 6-7
A BAL.K=BDGT.K-TOTC.K 6-8
A BDGT.K=1000+RAMP(ANBDGT,START)*PVF.K 6-9
C ANBDGT=9E10 6-10
A SUPPLY.K=AFF.K+EGRADS.K 6-11
A AFF.K=TABXT(AFFT,PPNDX.K,.85,1.15,.05) 6-12
T AFFT=.0027/.0029/.0037/.0044/.0051/.0059/.0068 6-13
A PPNDX.K=SMOOTH(PAYNDX.K(1),ATTR) 6-14
C ATTR=1 6-15

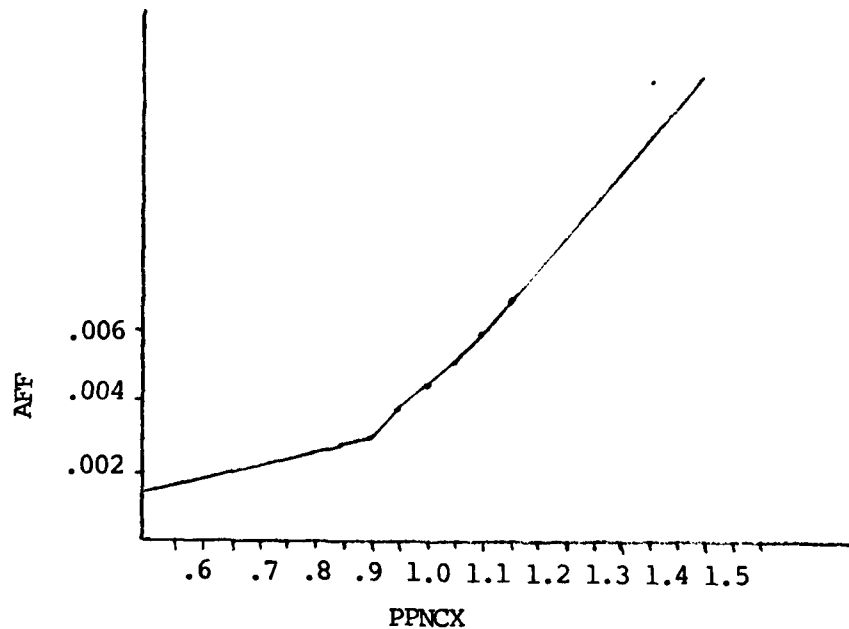
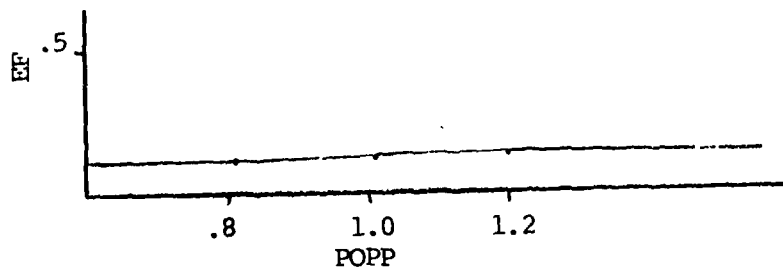


Fig. 23. Model Structure Representing Accessions



A $EGRADS.K = EF.K + TGRADS.K$ 6-16
 A $EF.K = TABHLEFT(POPP.K, .8, 1.2, .2)$ 6-17
 T $EFT = .24, .25, .26$ 6-18
 A $POPP.K = SMOOTH(CPNDX.K, TIS)$ 6-19
 C $TIS = 4$ 6-20
 A $TGRADS.K = 280000 + RAMP(EDGROW, 0)$ 6-21
 C $EDGROW = 6000$ 6-22

PR(1)	ACCESSION RATE ("PROMOTION TO 2LT") (OFFICERS/YR)	6-8
ACSNOP	ACCESSION OPTION (0 FOR PR(1)=ACSNR0 OR 1 FOR PR(1)=ACSN1)	6-1
GOAL	GOAL FOR ACCESSION RATE (OFFICERS/YR)	6-3
NEED	ACCESSION RATE NEEDED TO FILL VACANCIES (OFFICERS/YR)	6-4
LOSS	ESTIMATE OF NEXT YEAR'S LOSSES (OFFICERS)	6-5/7
BAL	BALANCE LEFT IN THE COST CONSTRAINT BUDGET (\$000)	6-8
BDGT	BUDGET COST CONSTRAINT (\$000)	6-9
TOTC	PRESENT VALUE OF TOTAL ACCUMULATED COSTS (\$000)	10-8
ANBDGT	ANNUAL BUDGET GROWTH RATE (\$000/YR)	6-10
SUPPLY	SUPPLY OF ENGINEERS AVAILABLE TO THE AIR FORCE (ENGINEERS)	6-11
AFF	AIR FORCE'S FRACTION OF ENGINEER GRADUATES (PERCENT)	6-12
PPNDX	PAY INDEX AS PERCEIVED BY PROSPECTIVE OFFICERS (DIMENSIONLESS)	6-1
PAYNDX	PAY INDEX (DIMENSIONLESS)	3-13
ATTR	AVERAGE TIME TO RECRUIT-DELAY FROM PAY RAISE TO ACCESSION RESPONSE (YRS)	6-15
EGRADS	ENGINEERING GRADUATES (ENGINEERS)	6-16
EF	ENGINEERING FRATION OF TOTAL GRADUATES (ENGINEERS)	6-17
POPP	OPPORTUNITY PERCEIVED BY STUDENTS FOR AN ENGINEERING CAREER (INDEX)	6-19
TIS	TIME IN SCHOOL AVERAGE DELAY BETWEEN A STUDENT SELECTING AN ENGINEERING CURRIC- ULUM AND GRADUATION (YRS)	6-20
TGRADS	TOTAL COLLEGE GRADUATES (STUDENTS)	6-21
EDGROW	GROWTH RATE FOR COLLEGE GRADUATES (STUDENTS/YR)	6-22

Fig. 23--Continued

This constant specifies the rate at which the maximum of cumulative total costs increases each year. The FIFGE function in equation 6-3 "selects the First argument IF the third is Greater than or Equal to the fourth [Pugh, 1976:27]." So in this case

$$\text{GOAL} = \begin{cases} \text{NEED if BAL} \geq 0 \\ 0 \text{ if BAL} < 0. \end{cases}$$

The fraction of engineer graduates willing to join the Air Force is hypothesized to be a function of the perceived ratio of military to civilian salaries expected during the time period of an initial obligation to the Air Force. The index of this ratio is the perceived pay index (PPNDX) which is the "smoothed" value of the normal pay index for Lieutenants calculated under the military pay section. The delay constant provided to the SMOOTH function represents the assumed lag between increases in military pay and the response in recruiting.

The fraction of total graduates with engineering degrees is assumed to correspond to the perceived opportunity for high salaries in an engineer job after graduation as shown in the graph of Figure 23. In this case, the delay represents the average time in school from selection of an engineering curriculum to graduation.

The total graduates variable is provided to allow users to enter in the demographic expectation for college graduates and assess the impact on the accession rate.

In conclusion, the accession structure has been designed to enable users of the model to assess the impact of what has been called the only true constraints for military manpower planning studies (Foch, 1977): (1) the size and composition of the United States manpower pool, and (2) the condition of the private sector labor market. To these constraints, an artificial cost constraint is added for use in generating equal cost alternatives for effectiveness comparisons.

Section 7: Promotion Structure⁸

In the real Air Force personnel system, officers normally serve in a rank until they have sufficient time in grade to be considered for promotion in the "primary" zone for the next higher rank. Each year, a quota for promotion is established based on a percentage of officers in the year group coming into the primary zone. This percentage, called the promotion opportunity, is established by management and legislative policies. Within this quota, promotion boards are given limited authority to select individuals below the primary zone as well as individuals above the zone. But still the total promotion rate is determined by the size of the year group and the promotion opportunity.

⁸This structure uses many of the features in Carpenter and Lacey's (1977:71-84) representation of promotion.

The time in grade requirements and promotion opportunities used in the initial runs of the model are shown in Table XI. The promotion opportunity values could be varied in subsequent runs to reflect a promotion opportunity for non-rated 28XX officers based on historical selection rates.

TABLE XI
PROMOTION OPPORTUNITIES (PO) AND REQUIRED
TIMES IN GRADE (TIG)

Grade	TIG	PO
Lieutenant	4	1
Captain	8	.9
Major	5	.7
Lieutenant Colonel	5	.5

The promotion structure shown in Figure 24 is designed to capture the effects of different sized year groups (commonly referred to as "humps") moving through the system. To represent these year groups in the model "pipeline" vectors are used to accumulate rates of flow into the various support officer levels (SUPPORT(I2TO5)) and store them until needed to calculate the outgoing promotion rates. For example, the accession rate is accumulated in the first element of the vector PIPE2 (equation 7-2) for a period of one year, at which time the SHIFTL function (equation 7-1) advances the contents of PIPE2 by one

NOTE SECTION 7: PROMOTIONS

```

R PR.KL(2)=(1-VSRF.K(2))*PO(2)*OUT2.K 7-8
A OUT2.K=SHIFTL(PIPE2.K,1) 7-1
L PIPE2.K(1)=PIPE2.J(1)+DT*PR.JK(1) 7-2
N PIPE2(JIT05)=PIPE2I(JIT05) 7-3
T PIPE2I=0/315/276/265/155 7-4

R PR.KL(3)=PO(4)*OUT3.K 7-5
T PO=1/1/1/.9/.7/.5 7-6
A OUT3.K=SHIFTL(PIPE3.K,1)-ALOSS3.K 7-7
L PIPE3.K(1)=PIPE3.J(1)+DT*PR.JK(2) 7-8
N PIPE3(JIT09)=PIPE3I(JIT09) 7-9
T PIPE3I=0/104/127/135/99/133/115/168/210 7-10
A ALOSS3.K=SUMV(LOSS3.K,2,9)/8 7-11
L LOSS3.K(1)=LOSS3.J(1)+DT*LOSS3R.JK 7-12
A DLOSS3R.K=SHIFTL(LOSS3.K,1) 7-13
N LOSS3(JIT09)=LOSS3I(JIT09) 7-14
T LOSS3I=0/0/0/0/0/0/0/0 7-15
R LOSS3R.KL=VSR.JK(3)-TR.JK(3) 7-16

R PR.KL(4)=PO(5)*OUT4.K 7-17
A OUT4.K=SHIFTL(PIPE4.K,1)-ALOSS4.K 7-18
L PIPE4.K(1)=PIPE4.J(1)+DT*PR.JK(3) 7-19
N PIPE4(JIT06)=PIPE4I(JIT06) 7-20
T PIPE4I=0/110/98/89/105/111 7-21
A ALOSS4.K=SUMV(LOSS4.K,2,6)/5 7-22
L LOSS4.K(1)=LOSS4.J(1)+DT*LOSS4R.JK 7-23
A DLOSS4R.K=SHIFTL(LOSS4.K,1) 7-24
N LOSS4(JIT06)=LOSS4I(JIT06) 7-25
T LOSS4I=0/0/0/0/0/0 7-26
R LOSS4R.KL=VSR.JK(4)-VSRP04.K-TR.JK(4) 7-27
A VSRP04.K=DELAYP((1-PO(5))*OUT4.K,ATAP4,PO*AJ0) 7-27.1
C ATAP4=3 7-27.2

R PR.KL(5)=PO(6)*OUT5.K 7-28
A OUT5.K=SHIFTL(PIPE5.K,1)-ALOSS5.K 7-29
L PIPE5.K(1)=PIPE5.J(1)+DT*PR.JK(4) 7-30
N PIPE5(JIT06)=PIPE5I(JIT06) 7-31
T PIPE5I=0/81/62/55/51/17 7-32
A ALOSS5.K=SUMV(LOSS5.K,2,6)/5 7-33
L LOSS5.K(1)=LOSS5.J(1)+DT*LOSS5R.JK 7-34
A DLOSS5R.K=SHIFTL(LOSS5.K,1) 7-35
N LOSS5(JIT06)=LOSS5I(JIT06) 7-36
T LOSS5I=0/0/0/0/0/0 7-37
R LOSS5R.KL=VSR.JK(5)-VSRP05.K-TR.JK(5) 7-38
A VSRP05.K=DELAYP((1-PO(6))*OUT5.K,ATAP5,POLTC5)
C ATAP5=2 7-40

```

Fig. 24. Model Structure Representing Promotions

PR(1)	PROMOTION RATE FROM RANK 1 (FOR 1-2 TO 5)	7-8,
PIPE2(J)	LTS WHO ENTERED J-1 YEARS EARLIER (OFFICERS)	7-2
PO(1)	PROMOTION OPPORTUNITY TO GRADE 1 (PER CENTAGE)	7-6
OUT3	PROMOTION RATE TO CAPT 8 YEARS EARLIER (OFFICERS/YR)	7-7
PIPE3(J)	OFFICERS PROMOTED TO CAPT J YEARS EARLIER (OFFICERS/YR)	7-8/9
ALOSS3(J)	AVERAGE OF LOSS PER YEAR GROUP OVER THE PAST 8 YEARS (OFFICERS)	7-11
PIPE31(J)	CURRENT 28XX CAPTS WITH J-1 YRS TIME IN GRADE (OFFICERS)	7-18
LOSS3(J)	CAPTS LOST J-1 YEARS EARLIER (OFFICERS)	7-12/1
DLOS3R	CAPTS LOST 8 YEARS EARLIER I.E.=LOSS3(9) (OFFICERS)	7-13
LOSS3I(J)	ZERO FOR EACH J	7-15
LOSS3R	TOTAL LOSS RATE FOR CAPTS (OFFICERS/YR)	7-16
OUTX, PIPEX, ALOSSX, PIPEXI, LOSSX, DLOSXR, LOSSXI	AND LOSSXR ARE DEFINED IN AN ANALOGOUS MANNER FOR MAJS (X=4) AND LT COLS (X=5)	7-17/38
POR (1)	PASSED OVER SEPARATION RATE (OFFICERS/YR)	8-8/5
VSR0P4	PORTION OF VOLUNTARY SEPARATION RATE ATTRIBUTABLE TO PASSED OVER MAJS	7-27.1
ATAP4	AVERAGE TIME IN THE AIR FORCE AFTER PASS-OVER TO LTC (YRS)	7-27.2
POMAJ5	PASSED OVER MAJORS	
VSR0P5	PORTION OF VOLUNTARY SEPARATION RATE ATTRIBUTABLE TO PASSED OVER LT COLS	7-39
ATAP5	AVERAGE TIME IN THE AIR FORCE AFTER PASS-OVER TO COL (YRS)	7-48
POLTCS	PASSED OVER LT COLONELS	

Fig. 24--Continued

element, discards the last element, and sets the first element back to zero. The value of OUT2 is also reset to equal the last element of PIPE2. Thus the fifth element of PIPE2 represents the number of officers who entered the Air Force four years earlier and are therefore completing their initial obligation and are eligible for promotion to Captain. Since the percentage choosing to separate at the end of this initial obligation is represented by VSRF.K(2), the promotion rate to Captain is

$$(1 - \text{VSRF.K}(2)) * \text{PO}(3) * \text{OUT2.K}$$

per year as shown in equation 7-0.

If the user wishes to start the analysis with the actual current inventory, the PIPE2I elements 2 through 5 (equation 7-4) should all be set equal to the numbers of 28XX officers in the first four year groups as reflected in the current model (AFMPC, 1980b).

The promotion rates for Captains through Lieutenant Colonels are represented in a fashion similar to that used for Lieutenants with a few exceptions. The first exception is necessitated by the representation of the voluntary separation rate and transfer rate (described later) of Captains through Lieutenant Colonels as occurring over the entire period of time officers spend in these levels. Therefore, the accumulated loss (ALOSS3) of Captains, for example, must be deducted from the last element of PIPE3

before the promotion rate is determined as shown in equations 7-18 and 7-19. This average loss is calculated by using another pipeline vector, LOSS3, which accumulates the total losses for each year. The total of the last eight elements of this LOSS3 vector represents all Captains lost over the past eight years, one-eighth of which are attributable to the last year group.⁹

If the user wishes to initialize the model with the actual inventory of 28XX officers, each LOSSXI(I) should be set to zero and the pipeline vectors filled with the current levels of each year group. Although these levels do not represent the numbers who entered the rank, no losses will be deducted with the LOSSXI(I)'s equal to zero.

One assumption implied by equation 7-16 is that all voluntary losses of Captains are incurred from officers in the pipeline before the primary zone. In light of the severance allowance paid to officers forced out by pass-overs, this is not an unreasonable assumption.

However, it would be unreasonable to assume this for Majors and Lieutenant Colonels. For this reason the portion of the voluntary separation rate attributable to officers passed over for promotion are calculated by the DELAY function in equations 7-7.1 and 7-42. This rate is

⁹Although this may not be precisely accurate since Captains with less time in service are actually more apt to separate when the pay ratio is low, it is assumed to be a reasonable approximation.

then deducted from the losses accumulated to be later deducted from the rates out of the pipeline vectors.

To test the validity of the promotion rate structure, the simple voluntary separation rate and accession rate options were used with a fluctuating exogeneous input for accessions. The results of this test are shown in Figure 25. Note that four years after the accession rate ("1" on the graph) is "stepped up" from 300 to 350, the promotion rate to Captain ("2" on the graph) increases from about 200 per year to 230. And then eight years later the promotion rate to Major increases and so on through the promotion rate to Colonel ("6"). Thus the increase in accessions passes on through the system, attenuated by the loss rates and passovers as they go through. This demonstrates that the promotion structure does preserve the "humps" in experience categories as larger year groups pass through the system.

This structure may be criticized because of the fixed nature of promotion timing and opportunity, regardless of whether or not there are vacancies in the higher grades. If the study were focusing upon promotion policies for the entire Air Force officer force this would certainly be a weakness. But this investigation is more concerned about the total 28XX officer force and its experience level as indicated by the numbers of officers in each rank. The rank levels are used primarily as an input to the productive capacity function. This function was estimated based

PR(1)=1 PR(2)=2 PR(3)=3 PR(4)=4 PR(5)=5

8,920	87,500	175,000	261,500	350,000	12045
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[illegible]

Fig. 25. Test of Promotion Structure

on the current perceptions of the relative productivity of officers in the different ranks. Therefore, the rank levels of interest are those derived by assuming continuation of current promotion policies. Given this purpose, additional "accuracy" in promotion policies could invalidate the effectiveness indication provided by the productive capacity function.

Section 8: Separations
Due to Passovers

The previous section described how promotions are represented in the model. One loose end left to tie up from that discussion is the disposition of those officers who will not be promoted. The representation for promotion to Captain assumes that no one is passed over ($PO(3) \equiv 1$). However, for other promotions the promotion opportunity was less than 1.0 so that at least some officers are passed over. For Captains the outflow due to passovers is disaggregated from the voluntary separation rate. This is necessary to calculate the costs since Captains separating after being passed over are paid a severance pay while other Captains are not. This disaggregation is not necessary for Majors and Lieutenant Colonels since officers mandatorily retired from these ranks normally receive the same retirement benefits as officers voluntarily separating. So for these grades, the mandatory retirements are included in the voluntary separation rate.

The representation for Captains passed over for promotion to Major is shown in Figure 26. The basic assumption of this representation is that the number of Captains passed over continue in service at least until they are able to receive severance pay. Thus the forced separation rate (POR) is just a delay of the complement of the promotion rate as shown in equation 8-2. The effect of selective continuation policies could be approximated by increasing the average time after passover (ATAP3) constant which determines the average lag between an officer's being passed over and his separation. However, if a substantial percentage were expected to receive retirement benefits, the structure of this part should be modified.

NOTE SECTION 8: SEPARATIONS DUE TO PASSEOVERS

```

R POR.KL(1)=0 8-0
R POR.KL(2)=0 8-1
R POR.KL(3)=DELAYP((1-PD(4))*OUT3.K,ATAP3,POCPTS) 8-2
C ATAP3=2 8-3
R POR.KL(4)=0 8-4
R POR.KL(5)=0 8-5

POR (1)  PASSED OVER SEPARATION RATE (OFFICERS/YR)  8-0/5
PD (1)   PROMOTION OPPORTUNITY TO GRADE I (PER      7-6
          CENTAGE)
OUT3     PROMOTION RATE TO CAPT 8 YEARS EARLIER     7-7
          (OFFICERS/YR)
ATAP3    AVERAGE TIME IN THE AIR FORCE AFTER PASS-  8-3
          OVER TO MAJ (YRS)
POCPTS   PASSED OVER CAPTAINS                       8-2

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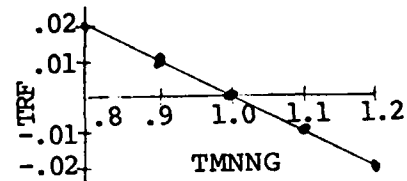
Fig. 26. Model Structure Representing Passovers

Section 9: Transfers

The last flow of personnel considered in the abstract of the real system is the net rate at which support officers enter or leave the 28XX career field. A discussion with the Air Force's 28XX career management office, Palace Vector Team Chief (Mackey, 1980) revealed that the key determinant of net transfer rates is the total 28XX manning. Grade manning considerations are subsidiary to the availability of personnel with the appropriate technical background. Transfers are far less significant in alleviating shortfalls than one might speculate; the net growth for transfers from mid-1979 to mid-1980 was only 1 percent with extensive management devoted to a "cross-flow program." For these reasons, the transfer rate is represented in the model by simply applying the same percentage growth (or decrease) factor to each rank for Captain through Lieutenant Colonel. This factor is slightly positive when the career area is undermanned and slightly negative when it's overmanned, as depicted in the graph of Figure 27. The transfer rate for Lieutenants is assumed to be zero in light of the Air Force's objective to "Maximize the assignment and utilization of all officers on their initial term of obligated service in a single utilization field [USAFPP, 1978:2-7]."

NOTE SECTION 9: TRANSFERS

R TR.KL(I)=0
R TR.KL(I3T05)=RANK.K(I3T05)*TRF.K
A TRF.K=TABLE(1RFT,TMNG.K,.8,1.2,1)
T TRFT=.02/.01/0/-.01/-.02



TR(I)	NET TRANSFER RATE (INTO+, OUT-) FOR	9-0/1
	RANK I (OFFICERS/YR)	
RANK(I)	ASSIGNED IN RANK I (OFFICERS)	1-5
TRF	TRANSFER RATE FACTOR (PERCENT)	9-2

Fig. 27. Model Structure Representing Transfers

Section 10: Cumulative
Cost Calculations

The representation of personnel levels and rates discussed so far form the complete basis for assessing the effectiveness of alternative retention proposals. This section builds on that structure to provide users an approximate estimate of the costs associated with different proposals. The composition of the total cost estimate is shown in equation 10-0 of Figure 28. Each component of total costs will be described individually in the following paragraphs.

Annual Personnel Costs. Annual personnel costs which include all normal recurring personnel expenses such as salaries and insurance, are accumulated in an annual cost level for each rank as shown in equation 10-4 of Figure 28. This level is determined by a rate which is represented by multiplying the average annual costs for a rank by the level for that rank. Then the costs for each rank are totalled to get

NOTE SECTION 10: CUMULATIVE COST CALCULATIONS
NOTE TOTAL COSTS

A TOTC.K=TSEPC.K+ACCC.K+FSC.K+TANNC.K+VRETC.K 10-0
NOTE PRESENT VALUE FACTOR

A PVF.K=1/(1+DISCNT)**(TIME-START) 10-1
C DISCNT=.1 10-2

NOTE ANNUAL PERSONNEL COSTS

A TANNC.K=SUM(ANNC.K) 10-3
L ANNC.K(1)=ANNC.J(1)+DT*ANNCR.JK(1) 10-4
N ANNC(1)=0 10-5
R ANNCR.KL(1)=0 10-6
L ANNC.K(I2T05)=ANNC.J(I2T05)+DT*ANNCR.JK(I2T05) 10-7
N ANNC(I2T05)=ANNC(I2T05-1) 10-8
T ANNCI=0/0/0/0 10-9
R ANNCR.KL(I2T05)=RANK.K(I2T05)*ANNCF(I2T05)*PVF.K 10-10
A ANNCF.K(1)=0 10-11
A ANNCF.K(2)=AFCF(2)*(MP.K(1)+MP.K(2))/2000 10-12
A ANNCF.K(I3T05)=AFCF(I3T05)*MP.K(I3T05)/1000 10-13
T AFCF=0/.93/.99/.98/.97 10-14

NOTE VOLUNTARY SEPARATION COSTS

A TSEPC.K=SUM(SEPC.K) 10-15
L SEPC.K(I1T05)=SEPC.J(I1T05)+DT*VSR.JK(I1T05)*
X SEPCF.J(I1T05)*PVF.J 10-16
N SEPC(I1T05)=SEPC(I1T05) 10-19
T SEPCI=0/0/0/0 10-20
A SEPCF.K(1)=0 10-21
A SEPCF.K(I2T05)=PCSC+RETC.K(I2T05) 10-22
C PCSC=4 10-23
A RETC.K(I1T05)=PRET(I1T05)*APRCNT(I1T05)*BASEF(I1T05)*
X MP.K(I1T05)*RPVF(I1T05)/1000 10-25
T PRET=0/0/.1/.9/1 10-26
N APRCNT(I1T05)=.5*(ATRSVC(I1T05)-20)+.025 10-27
T ATRSVC=0/0/20/20/24 10-28
N BASEF(I1T05)=BASEPI(I1T05)/MPI(I1T05) 10-29
T BASEPI=10895/14501/18961/22952/27803 10-30
N RPVF(I1T05)=(1-1/(1+DISCNT)**(I1T05)))/(1-1/(1+DISCNT)) 10-31
N N(I1T05)=LIFEXP-(21+ATRSVC(I1T05)) 10-32
C LIFEXP=70 10-33

Fig. 28. Model Structure for Estimating Costs

NOTE ACCESSION COSTS

L $ACCC.K = ACCE.J + DT * ACCCF + PR.JK(1) * PVF.J$ 10-34
 N $ACCC = 0$ 10-35
 C $ACCCF = 27$ 10-36

NOTE VESTED RETIREMENT COSTS

L $VRETC.K = VRETC.J + DT * PR.JK(15) * SEPCF.J(15) * PVF.J$ 10-37
 N $VRETC = 0$ 10-38

NOTE FORCED SEPARATION COSTS

L $FSC.K = FSC.J + DT * (POR.JK(3)) * FSCF * PVF.J$ 10-39
 N $FSC = 0$ 10-40
 N $FSCF = PCSC + SEVPAY$ 10-41
 C $SEVPAY = 15$ 10-42

TOTC	PRESENT VALUE OF TOTAL ACCUMULATED COSTS (\$000)	10-0
PVF	PRESENT VALUE FACTOR (DIMENSIONLESS)	10-1
DISCNT	DISCOUNT INTEREST RATE (PERCENT)	10-2
TANNC	TOTAL ANNUAL PERSONNEL COSTS (\$000)	10-3
ANNC(I)	TOTAL ANNUAL COSTS FOR RANK I (\$000)	10-7
ANNCR(I)	ANNUAL COST RATE FOR RANK I (\$000/YR)	10-10
RANK(I)	ASSIGNED IN RANK I (OFFICERS)	1-5
ANNCF(I)	ANNUAL COST FACTOR FOR RANK I	10-1
ACFC(I)	AIR FORCE COST FRACTION FOR OFFICERS OF RANK I (PERCENT)	
MP(I)	MILITARY PAY FOR RANK I (\$)	4-12
TSEPC	TOTAL ACCUMULATED VOLUNTARY SEPARATION COSTS (\$000)	10-15
SEPC(I)	ACCUMULATED VOLUNTARY SEPARATION COSTS FOR RANK I (\$000)	10-18
SEPCF(I)	VOLUNTARY SEPARATION COST FACTOR FOR RANK I (\$000/OFFICER)	10-22
PCSC	PERMANENT CHANGE OF STATION COSTS (\$000)	10-23
RETC	RETIREMENT COSTS (\$000)	10-24
PRET	PERCENTAGE OF RETIREMENTS FROM RANK I (PERCENT)	10-26
APRCNT	AVERAGE PERCENT OF BASE PAY AUTHORIZED RETIREES FROM RANK I (PERCENT)	10-27
AYRSVC(I)	AVERAGE YEARS SERVICE OF RETIREES FROM RANK I (YEARS)	10-28
BASEF(I)	BASE PAY AS A FRACTION OF MILITARY PAY (REGULAR MILITARY COMPENSATION) FOR RANK I (PERCENT)	10-29

Fig. 28--Continued

E4SERI(1)	INITIAL BASE PAY FOR RANK I (\$)	10-30
MP1(1)	INITIAL MILITARY PAY (REGULAR MILITARY COMPENSATION) FOR RANK I (\$)	4-14
RPVF(1)	PRESENT VALUE FACTOR FOR FUTURE PAY FOR RETIREES FROM RANK I (DIMENSIONLESS)	10-31
N(1)	AVERAGE YEARS RETIREES FROM RANK I ARE PAID (YEARS)	10-32
LIFEXP	LIFE EXPECTANCY (YEARS)	10-33
ADCC	ACCUMULATED ADDESSION COSTS (\$000)	10-34
ADCCF	ADDESSION COST FACTOR (\$018/OFFICER)	10-36
PR(1)	ADDESSION RATE (PROMOTION TO 2LT) (OFFICERS/YR)	5-8
VRETC	ACCUMULATED VESTED RETIREMENT COSTS FOR LT COLS PROMOTED TO COL (\$000)	10-37
PR(1)	PROMOTION RATE FROM RANK I (FOR 1-2 TO 5)	7-8
FSC	ACCUMULATED FORCED SEPARATION COSTS (\$000)	10-39
FSCF	FORCED SEPARATION COST FACTOR (\$000/OFFICER)	10-41
SEVPAY	SEVERANCE PAY (\$000/OFFICER)	10-42
FOR (1)	PASSED OVER SEPARATION RATE (OFFICERS/YR)	8-2/5

Fig. 28--Continued

the total annual costs. Since the military pay rates are assumed to fluctuate, the average annual costs are computed using the Air Force cost fraction (AFCF) constant. This factor accounts for the tax advantage included in Regular Military Compensation (RMC) which doesn't cost the Air Force. This decrease is partially offset by additional expenses not included in RMC such as uniform allowances and insurance. The AFCF table was estimated by dividing the fiscal year 1979 composite rates for each grade without special pay (AFP 173-13, 1980) by the 1979 RMC rates (Assistant Director, Compensation, 1979).

Voluntary Separation Costs. The present value of voluntary separation costs for each grade are accumulated by the SEPC level of equation 10-18 in Figure 28. The rate at which this level increases is determined by multiplying the voluntary separation rate by a separation cost factor (SEPCF) representing the average cost to the Air Force for each officer separating from the grade in question. For all ranks this includes the cost to relocate the officer. The present value of projected retirement benefits is included in the SEPCF for those officers eligible for retirement (some prior enlisted Captains and almost all Majors and Lieutenant Colonels). The retirement cost factors are calculated in the model as shown in equations 10-22 to 10-33 to allow users to easily change the factors, such as the discount rate (DISCNT) used in estimating these costs.

Accession Costs. The accession costs are estimated by simply multiplying the accession rate (PR(1)) by the average accession cost for all officers (AFP 173-13, 1980).

Vested Retirement Costs. Since Colonels were defined as being external to the system, it is necessary to associate some cost for the retirement benefits which those Lieutenant Colonels being promoted out of the system have already earned. If these vested retirement costs were not included, the costs of proposals which generated different promotion rates to Colonel could not be compared equitably. Increases in the cumulative vested retirement costs are calculated simply by multiplying the rate of all officers promoted to Colonel by the same separation cost factor (SEPCF) used for Lieutenant Colonels voluntarily separating from the Air Force.

Forced Separation Costs. As depicted in Figure 28 equations 10-39 to 10-42, increases in cumulative forced separation costs are calculated by simply multiplying the sum of relocation costs and severance pay by the rate of separations due to passovers (POR). These increases are accumulated in the forced separation cost level.

This completes the description of the structure of the model which was designed to simulate the flow of officers in the 28XX career area, and calculate the associated effectiveness measures and cost estimates. As

indicated at the beginning of this chapter, the assessment of a model's validity rests primarily on an evaluation of the model's detailed structure. However, a model should also be thoroughly tested to confirm that the behavior of the total model corresponds to that of the actual system (Forrester, 1961:115-129). The primary focus of such tests should be upon the nature of the dynamic characteristics represented by the model. In particular, the interest is in the direction and extent of major changes to the real system. The next section describes a few samples of preliminary runs of the model made to demonstrate the dynamic characteristics of the model.

Preliminary Model Test Runs

This section presents several runs conducted primarily to demonstrate the capabilities which the model has been designed to provide. The alternatives considered in these runs of the model are purely hypothetical and are presented only to illustrate potential applications of the model. No sensitivity analysis has been performed to identify the key variables nor have data collection efforts been completed to indicate even the range of reasonable values for many of the parameters of the model. Therefore, any conclusions based upon these examples, must be viewed as tentative at best.

The first run was made with all the equations and parameter values set as discussed previously in this

chapter. This version of the model was designed to represent current compensation policies. Some of the results from this run are shown in Figure 29 and 30. The "T"'s in Figure 29 represent the total 28XX manning percentage while the numbers represent the percentage for their respective grades: "2" for 0-2's plus 0-1's, through "5" for 0-5's. This plot indicates that, given all the assumptions incorporated in the model, the system would be expected to remain reasonably stable but with slightly decreasing total manning levels and more dramatic decreases in the manning of major authorizations starting around the middle of this decade.

The effect of the decreasing number of Majors is clearly evident in the rapid decrease in the productive capacity indicator shown in Figure 30. This figure illustrates one important point about the validity of this model. This run assumes that there will be no change in compensation policies. This may not be representative of the true system since management could be expected to respond with some additional incentives well before the productive capacity fell below 40 percent. Of course, the purpose of the model was to answer such questions as: What will happen if there are no changes in the compensation policies?

One alternative to the current compensation policy would be to offer some sort of accession bonus to attract more engineers into the Air Force. This can be incorporated

TMNG=T MNNG(2)=2 MNNG(3)=3 MNNG(4)=4 MNNG(5)=5

	0.000	.750	1.500	2.250	3.000	T2345
1980.8.	---	3 -5-T	---	2	---	T4
.	.	3 5 T	.	2	.	T4
.	.	3 5 T4	.	2	.	.
.	.	3 5T 4	.	2	.	.
.	.	3 5T 4	.	2	.	.
.	.	3 5T 4	.	2	.	.
.	.	3 5T 4	.	2	.	.
.	.	3 5T 4	.	2	.	.
.	.	3 5T 4	.	2	.	.
.	.	3 5T 4	.	2	.	.
1983.2.	---	3 -5T -4	---	2	---	.
.	.	3 5T 4	.	2	.	.
.	.	3 5T 4	.	2	.	.
.	.	3 .T 4	.	2	.	T5
.	.	3 .T 4	.	2	.	T5
.	.	3 .T 4	.	2	.	T5
.	.	3 .T 4	.	2	.	T5
.	.	3 .T 4	.	2	.	T5
.	.	3 .T4	.	2	.	T5
.	.	3 .T4	.	2	.	45
1985.7.	---	3 -T5	---	2	---	T4
.	.	3 .T 5	.	2	.	T4
.	.	3 4T 5	.	2	.	.
.	.	3 4T 5	.	2	.	.
.	.	3 4.T 5	.	2	.	.
.	.	3 4 T 5	.	2	.	.
.	.	3 4 T 5	.	2	.	.
.	.	3 4 T 5	.	2	.	.
.	.	3 4 T 5	.	2	.	.
1988.2.	---	3-4 -T -5	---	2	---	.
.	.	3 4 T 5	.	2	.	.
.	.	34 T 5	.	2	.	.
.	.	34 T 5	.	2	.	.
.	.	3 T 5	.	2	.	34
.	.	43 T 5	.	2	.	.
.	.	43 T. 5	.	2	.	.
.	.	3 T. 5	.	2	.	34
.	.	43 T. 5	.	2	.	.
1990.7.	---	43 -T -5	---	2	---	.
.	.	43 T. 5	.	2	.	.

Fig. 29. Manning Projections with Current Compensation Policies

PROD=1

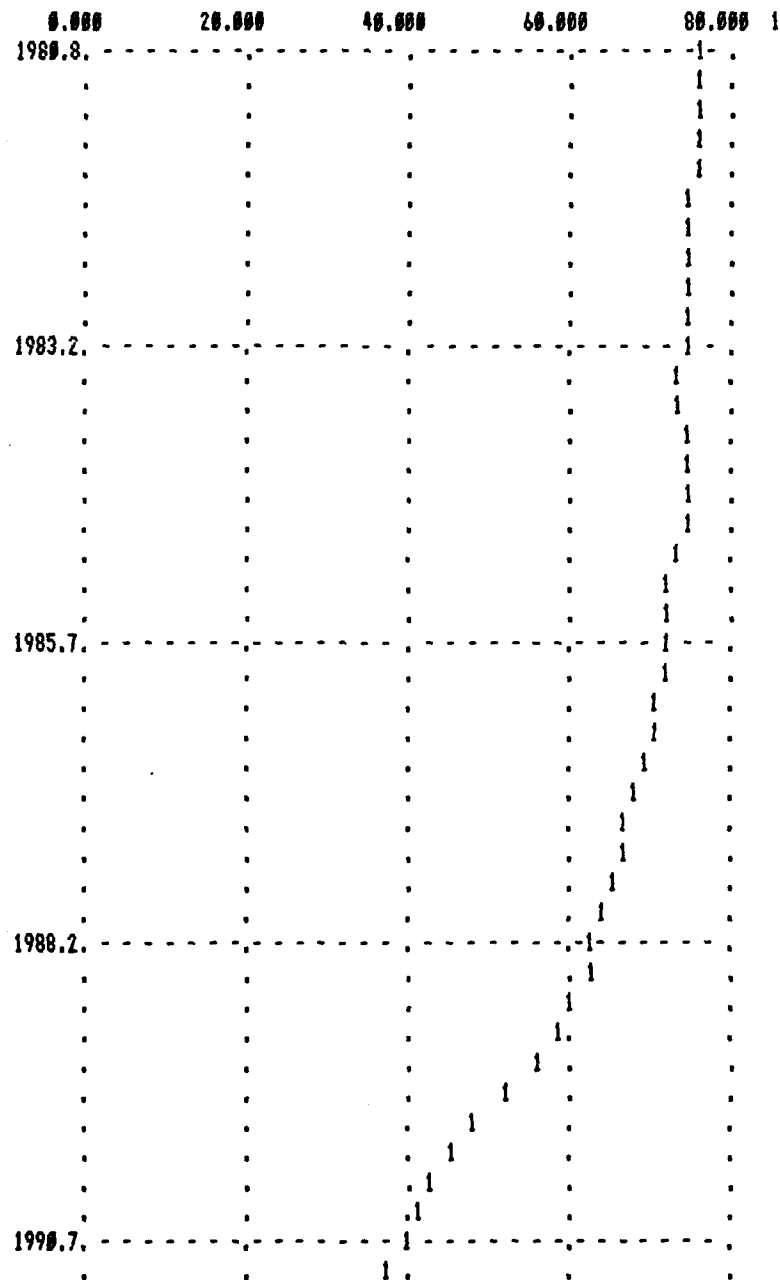


Fig. 30. Productive Capacity Projection with Current Compensation Policies

into the model by changing the policies used to calculate a Second Lieutenant's salary (MP(1)). This was accomplished in the next sample run by changing equations 4-19 and 4-20 to:

$$\text{PRCNT.K(11T06)} = \text{PRCNTI(11T06)} \quad (4-19)$$

and
$$\text{PRCNTI} = 1/.91/.94/.99/1.05/1.06 \quad (4-20)$$

The number one in the first element of PRCNTI causes the model to strive for full comparability between Second Lieutenants' and their civilian engineer counterparts' salaries. The remaining elements represent the current ratio of average civilian salaries to civilian engineer salaries, as represented in the estimates included in this version of the model. The results obtained from this run of the model are shown in Figure 31 and 32.

The accumulated costs estimated for this run were \$757,000,000, roughly \$40,000,000 more than the cost calculated by the run simulating current policies. With this additional expense the Air Force's total 28XX manning, shown in Figure 31, stays above 75 percent as compared to dropping to 67 percent in the previous run. However, this increase in manning caused no substantial shift in the projected productive capacity curve shown in Figure 32 when compared to the base case in Figure 30. Any differences between these two curves is too small for the productive capacity measure to distinguish the preferred alternative with confidence.

TNNG=T MNNG(2)=2 MNNG(3)=3 MNNG(4)=4 MNNG(5)=5

	0.000	.750	1.500	2.250	3.000	T2315
1980.8.	-3	-5-T	-2	-2	-2	T4
.	3	5 T	.	2	.	T4
.	3	5 T4	.	2	.	.
.	3	5T 4	.	2	.	.
.	3	5T 4	.	2	.	.
.	3	5T 4	.	2.	.	.
.	3	5T 4	.	2.	.	.
.	3	5T 4	.	2.	.	.
.	3	5T 4	.	2.	.	.
1983.2.	-3	-5T-4	-2	-2	-2	.
.	3	5T 4	.	.2	.	.
.	3	5T 4	.	.2	.	.
.	3	.T 4	.	.2	.	T5
.	3	.5T4	.	.2	.	.
.	3	.5T4	.	.2	.	.
.	3	.5T4	.	.2	.	.
.	3	.5T4	.	.2	.	.
.	3	.5T	.	.2	.	T4
.	3	.T	.	.2	.	T45
1985.7.	-3	-.4T-	-2	-2	-2	T5
.	3	.4T	.	.2	.	T5
.	3	.4 T5	.	.2	.	.
.	3	.4. T 5	.	.2	.	.
.	3	.4. T 5	.	.2	.	.
.	3	.4. T 5	.	.2	.	.
.	3	.4. T 5	.	.2	.	.
.	3	.4. T 5	.	.2	.	.
.	3	.4. T 5	.	.2	.	.
1988.2.	-3-4	-.T-5	-2	-2	-2	.
.	3	.T 5	.	.	.	2. 34
.	3	.T 5	.	.	.	2. 34
.	43	.T 5	.	.	.	2.
.	43	.T 5	.	.	.	2.
.	4 3	.T 5	.	.	.	2.
.	4 3	.T 5	.	.	.	2.
.	4 3	.T 5	.	.	.	2.
.	4 3	.T 5	.	.	.	2.
1990.7.	-4-3	-.T-5	-2	-2	-2	.
.	4 3	T 5	.	.	.	2.

Fig. 31. Manning Projections Assuming Accession Bonus

[illegible]

123

It should be noted that beyond the 1990 time frame, however, the accession bonus would be expected to have a more dramatic long-term positive effect on productive capacity.

Another example of a compensation policy which can be simulated with the System Dynamics model is a general increase in compensation for all company grade officers to 95 percent of the civilian engineer salaries. The run shown in Figure 33 and 34 coupled this pay raise with a cost constraint placed on accession by setting the annual budget constant

$$\text{ANBDGT} = 111000 \quad (6-10)$$

Although this option reduced total costs to a little over \$583,000,000, with only minor changes in productive capacity, the stop in accession would obviously decrease productive capacity beyond 1990. In order for this policy to be compared with the previous one, ANBDGT would need to be adjusted so that the costs calculated for the two different runs would be approximately equal.

One last sample run is included to demonstrate the ability to change the anticipated scenario under which the policy is to be evaluated. Figures 35 and 36 represent the results from a run similar to the accession bonus run illustrated in Figures 31 and 32. For this later run, however, the projected demand in the private sector was assumed to grow in the long run at an index value of four per year (where 100 represents the demand in 1961). This

TMNNG=T MNNG(2)=2 MNNG(3)=3 MNNG(4)=4 MNNG(5)=5

	0.000	.750	1.500	2.250	3.000	T2345
1980.8.	- - - - 3 - 5 - T - - - - -	- - - - 2 - - - - -	- - - - -	- - - - -	- - - - -	T4
.	3 5 T	2				T4
.	3 5 T 4	2				
.	3 5 T 4	2				
.	3 5 T 4	2				
.	3 T 4	2				T5
.	3 T 4	2				T5
.	3 T 4	2				T5
.	3 T5 4	2				
.	3 T5 4	2				
1983.2.	- - - - 3 - T5 - 4 - - 2 - - - -	- - - - -	- - - - -	- - - - -	- - - - -	
.	3 T5 4 2					
.	3 T5 24					
.	3 T25 4					
.	3 T2 .5 4					
.	32 T .5 4					
.	2 3 T .5 4					
.	2 3 T .5 4					
.	2 3 T .54					
.	2 3 T .4					45
1985.72	- - - - 3 T - .45 - - - - -	- - - - -	- - - - -	- - - - -	- - - - -	
2	3 T .4 5					
2	3 T 4 5					
2	3 T 4 5					
2	3 T 4. 5					
2	3 T 4. 5					
2	3 T 4. 5					
2	3 T 4. 5					
2	3 T 4. 5					
2	3 T 4. 5					
2	3 T 4. 5					
1988.22	- - 3 T 4 - - - - 5 - - - - -	- - - - -	- - - - -	- - - - -	- - - - -	
2	3 T 4 . 5					
2	3 T 4 . 5					
2	3 T 4 . 5					
2	3 T 4 . 5					
2	3 T 4 . 5					
2	3 T 4 . 5					
2	3 T 4 . 5					
2	3 T 4 . 5					
2	3 T 4 . 5					
2	3 T 4 . 5					
1990.72	- 3 T 4 - - - - 5 - - - - -	- - - - -	- - - - -	- - - - -	- - - - -	
2	3 T 4 . 5					

Fig. 33. Manning Projection with Increased Compensation for all Company Grade Officers and a Cost Constraint on Accessions

PROD=1

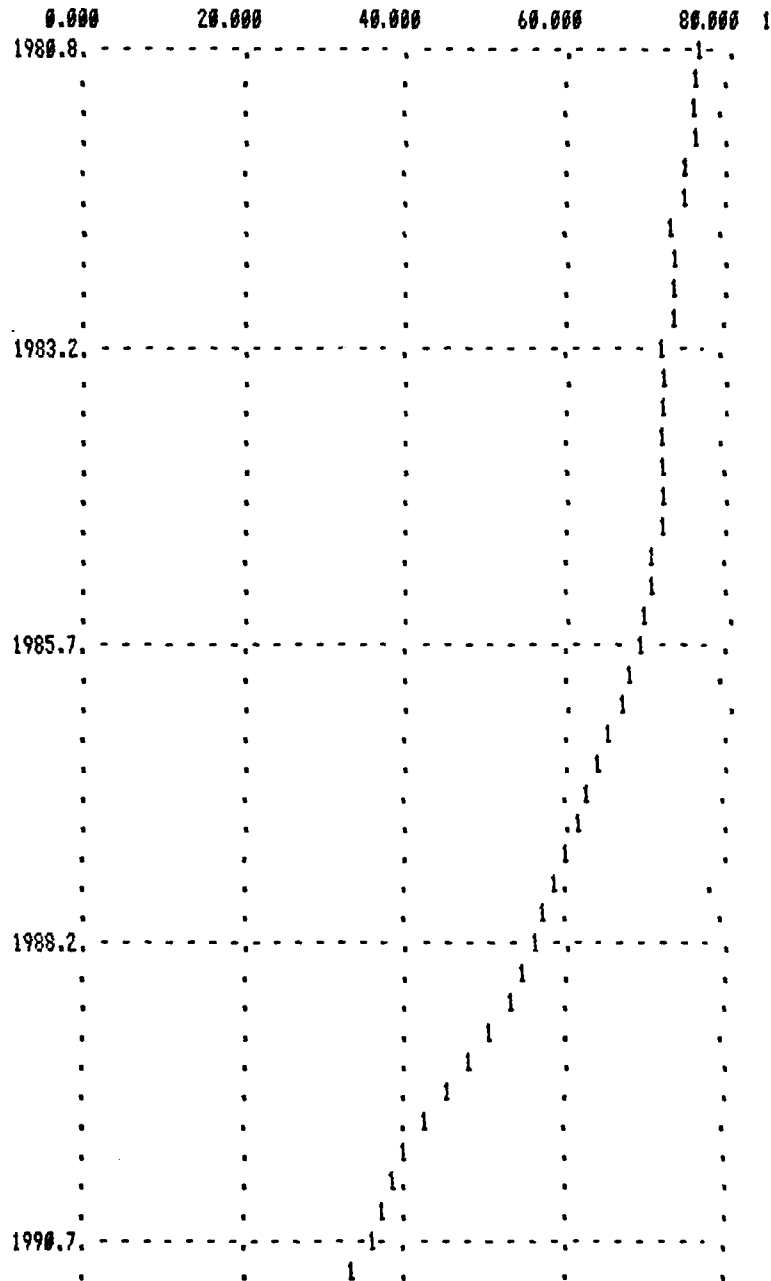


Fig. 34. Productive Capacity Projection with Increased Compensation for all Company Grade Officers and a Cost Constraint on Accessions

TMNG=T MNNG(2)=2 MNNG(3)=3 MNNG(4)=4 MNNG(5)=5

	0.000	.750	1.500	2.250	3.000	T2345
1980.8.	3	5-T		2		T4
.	3	5 T		2		T4
.	3	5 T4		2		
.	3	5T 4		2		
.	3	5T 4		2		
.	3	5T 4		2		
.	3	5T 4		2		
.	3	5T 4		2		
.	3	5T 4		2		
1983.2.	3	5T 4		2		
.	3	5T 4		.2		
.	3	5T 4		.2		
.	3	.T 4		.2		T5
.	3	.5T4		.2		
.	3	.5T4		.2		
.	3	.5T4		.2		
.	3	.5T4		.2		
.	3	.5T		.2		T4
.	3	.T		.2		T45
1985.7.	3	.4T			2	T5
.	3	.4T			2	T5
.	3	4 T5			2	
.	3	4. T 5			2	
.	3	4. T 5			2	
.	3	4. T 5			1	
.	3	4. T 5			2	
.	3	4. T 5			1	
.	3	4. T 5			1	
1988.2.	3	4. T 5			1	
.	3	.T 5			2	.34
.	3	.T 5			1	.34
.	43	.T 5			1	
.	43	.T 5			1	
.	43	.T 5			2	
.	43	.T 5			2	
.	43	.T 5			2	
.	43	.T 5			2	
1990.7.	4	3-T 5			2	
.	4	3 T 5			2	

Fig. 35. Manning Projections Assuming Accession Bonus, and Increasing Civilian Demand for Engineers

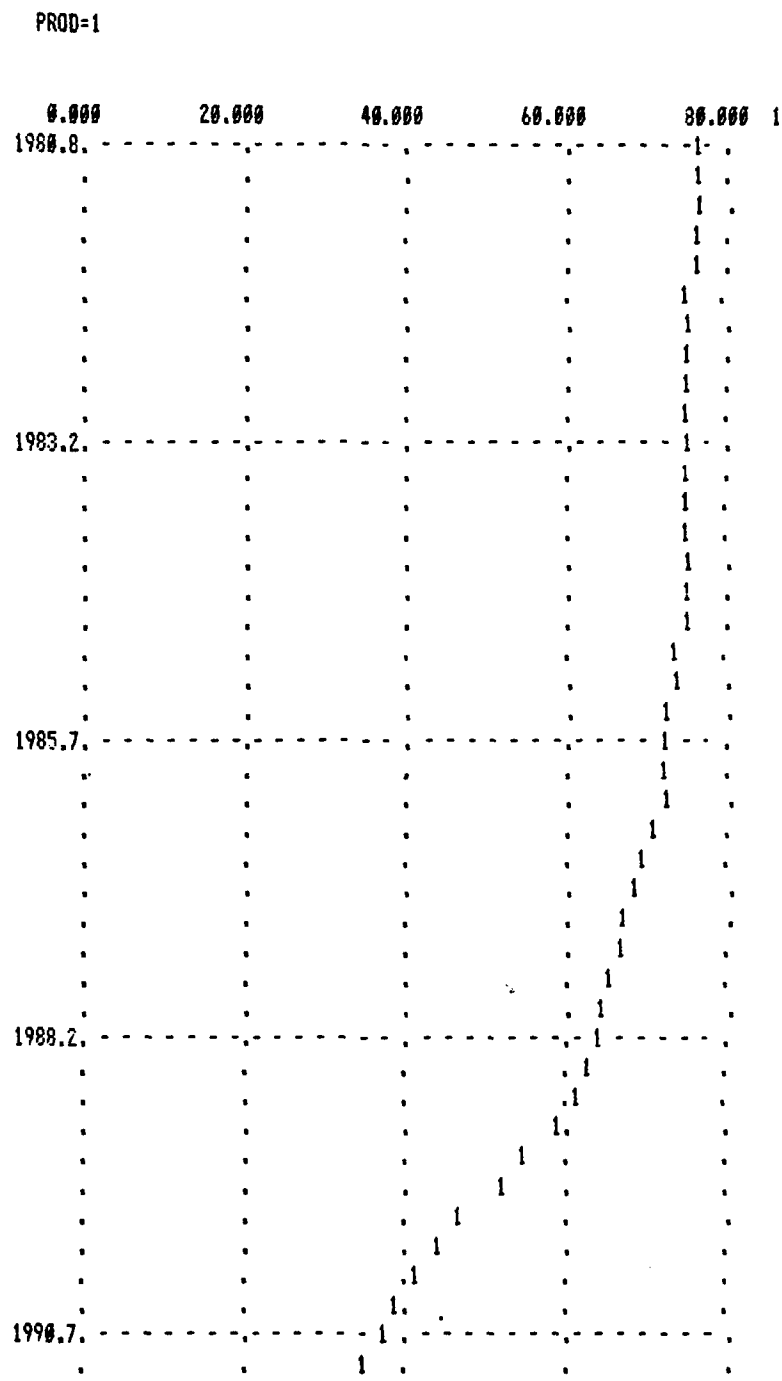


Fig. 36. Productive Capacity Projection Assuming Accession Bonus and Increasing Demand for Engineers

assumption was incorporated in the model by setting

$$\text{GROWTH} = 4 \qquad (5-21)$$

The present value of all costs calculated by this run were \$756,960,000 versus \$756,670,000 for the earlier run. This difference could hardly be considered substantial, given the approximate manner in which the model calculates costs. Similarly, the plots for manning and productive capacity are not substantially different. This demonstrates that the model is not sensitive to small changes in the civilian engineer demand index. This is not to say that larger variations in engineer demand would not have a substantial influence on the system's behavior.

These sample runs represent a small start toward many additional runs which should be accomplished to validate the model.

Summary

This chapter began by providing a general description of the concept of the Development Engineering Officer personnel system used to design a system dynamics model. The primary purpose of this model is to assist analysts in assessing the cost effectiveness implications of alternative engineering officer compensation policies. With this purpose in mind, it was suggested that a standard of adequacy rather than accuracy should be used in judging the validity of the model. To enable potential users to evaluate the model structure, each major section of the program

was described in detail. Following these detailed descriptions, the results of a few sample runs were presented to illustrate potential applications of the model.

The next chapter will conclude the report by addressing each the research objectives identified in Chapter I.

IV. Summary and Recommendations

Chapter I indicated that the research objectives were to:

1. Develop a list of propositions which can be used by the Air Force in formulating retention policy initiatives.
2. Develop a measure of effectiveness, or productive capacity, as a function of the numbers of development engineering officers assigned to each grade.
3. Construct a System Dynamics model for use in assessing the impact over time of compensation policies on the costs and capacity of the Air Force's Development Engineering officer force.

This chapter discusses each of these objectives individually, summarizing the findings of the research in pursuit of the objective and making suggestions for follow-on research.

Incentives

The results of the literature review and survey analysis conducted to achieve the first objective are described in Chapter II. A list of eighteen propositions derived from the literature review was presented. A more detailed review of several pertinent studies is provided in Appendix A. This list of propositions indicated that

utilization of skills, job challenge, self-fulfillment/ accomplishment, fair performance appraisals, recognition, autonomy on the job, favorable family opinions toward the Air Force, retirement benefits, merit promotion, rapid advancement, salary, having a "say" in future assignments, concerned and competent leadership, and prestige of the Air Force were all positively related to intentions to stay in the Air Force. Relocations, family separation, enforcement of standards, and the opportunity for civilian employment all were negatively associated with career intent. The literature review revealed no consensus as to which of the factors listed above are the more important determinants of engineering officers' career intent.

Chapter II also included a presentation of the Development Engineering Officer (28XX) responses to the Air Force Quality of Life Survey. These responses were compared to the responses of all Air Force officers to identify evidence indicating why the retention rates and career intent of engineering officers are lower than that of other officers. All of the significant differences identified by the analysis dealt with the economic standard factor which was defined in the survey as "Satisfaction of basic human needs such as food, shelter, clothing; the ability to maintain an acceptable standard of living [McNichols, et al., 1980]."

Typical of the 28XX responses, was the identification of the one factor which today would influence the

officer most not to make the Air Force a career. Forty-five percent of the 28XX respondents indicated that pay and allowances was the most significant factor versus only 22 percent of all officer respondents. The next most frequent response was the promotion system indicated by 10 percent of the 28XX respondents. Sixty-four percent of the replies selected by 28XX officers as the most significant negative career decision factors are directly related to monetary compensation. Because of such indications of the importance of compensation in determining career intent it was decided to focus upon retention related compensation policies for the remainder of the study.

To assess the merits of alternative compensation policies one must select some measure of the value of the forces expected from each alternative.

Productive Capacity

Assuming that the primary value of an engineering officer force is determined by what it is capable of doing, the most appropriate indicator of effectiveness of alternative retention proposals is the relative productive capacity of each. Accordingly, this study sought to develop an ordinal measure of productive capacity to compare the different development engineer officer forces expected to result from alternative compensation policies. Since this study focuses upon the tradeoffs between force size and experience levels, the productive capacity function was

designed to distinguish between large forces with relatively low experience levels and smaller more experienced forces. The experience level of a development engineering officer was assumed to be adequately indicated by the numbers of Lieutenants, Captains and Field Grade Officers in the career field at any given time. To estimate the relationship between these attributes and productive capacity, an experienced 28XX Air Force officer was interviewed.

The initial interviews with this decision maker were conducted to determine the form of the productive capacity function. The additive and multiplicative forms of this function were eliminated since the decision maker's preferences for any one attribute were not independent of the other attributes. This was true even within relatively small ranges of officers in each category. The lack of preference independence implied that the value to the decision maker of additional officers in any one of the grades depends upon the numbers of officers assigned in the other grades. Because of the interdependence among the attributes and feedback from the decision maker picturing the function as a smooth convex curve, it was hypothesized that the function could be adequately represented by a second order polynomial with cross-product terms.

To determine a more specific form and to estimate the parameters, the decision maker was asked to score sixty different combinations on a scale of zero to 100, with 100

defined as the capacity provided by a force which has 100 percent of its authorized manning in each grade. Step-wise regression of these scored combinations result in the following model:

$$P(L,C,F) = 12.9F + .03CF - 2F^2 + .6 \times 10^{-5} L^2 C^2 \\ - .4 \times 10^{-2} C^2 - 153.5 \text{ (Footnote 1)}$$

where L, C and F are the numbers of Lieutenants, Captains, and Field Grade Officers, respectively.

This model was subsequently tested against the decision maker's preferences for various force combinations and was found to be a reliable indicator of that decision maker's preference structure. It was assumed that this decision maker's preferences were indicative of the true productive capacity of the entire 28XX officer force. Based on this assumption, the function was used as a preliminary, approximate indicator of the relative productive capacity associated with alternative force structures.

This estimation process was intended only to provide preliminary results for use in sensitivity analyses. Should additional research in this area prove to be warranted, this research indicates that a good starting point would be to develop improved techniques for eliciting the decision maker's preference structure assuming interdependence of the attributes. One approach to tackling this

¹All coefficients were significant at the $\alpha \leq .015$.

problem may be to elicit preferences for increases in one attribute using the midvalue splitting technique (Keeney and Raiffa, 1976:94-96) while holding all other attributes constant. The data obtained from several such "slices" of the productive capacity surface would then be entered into a stepwise regression using the model

$$P = \sum_{i,j,k} \alpha_{ijk} L^i C^j F^k \quad i,j,k = 0,1, \text{ or } 2$$

Research such as that described above involving decision makers from a variety of organizations is necessary before any great degree of confidence can be placed in the adequacy of the productive capacity developed in this study. However, in any event, the measure of productive capacity of Air Force engineering officers is so subjective that probably only an approximate indicator is obtainable.

Although this function provides an indicator to compare forces with different numbers of officers in each rank, additional methodology is necessary to project the rank levels and to estimate the costs associated with each alternative. Accordingly, a System Dynamics model was developed to simulate the interrelationships between compensation policies, private sector competition, costs, development engineering officer manning, and productive capacity.

System Dynamics Model

Chapter III describes the System Dynamics model designed to assist analysts in assessing the cost-effectiveness implications of alternative engineering officer compensation policies. The model is based upon a simplified concept of the real development engineering officer personnel system. In this simplified concept all non-rated 28XX officers are viewed as being aggregated into four different rank levels: Lieutenant through Lieutenant Colonel. All flows into, out of, or between these levels are included in one of five different flows: accessions, promotions, voluntary separations, separations due to passovers (Captains only), and transfers between career areas. The levels of officers at any given time represent the accumulation of all past flows.

The general hypotheses underlying the model are depicted in the causal loop diagram shown in Figure 37. As described in Chapter III, the arrows with plus signs represent a positive relationship between the indicated variables; a negative sign indicates an inverse relationship. This figure leaves out many of the intermediate and more disaggregate variables to simply illustrate the general structure of the model. Ultimately, the key determinants of 28XX manning as represented in the model are the civilian demand for engineers and the military compensation policies. Under the current policy, all non-rated officers' salaries are determined by the government after considering the

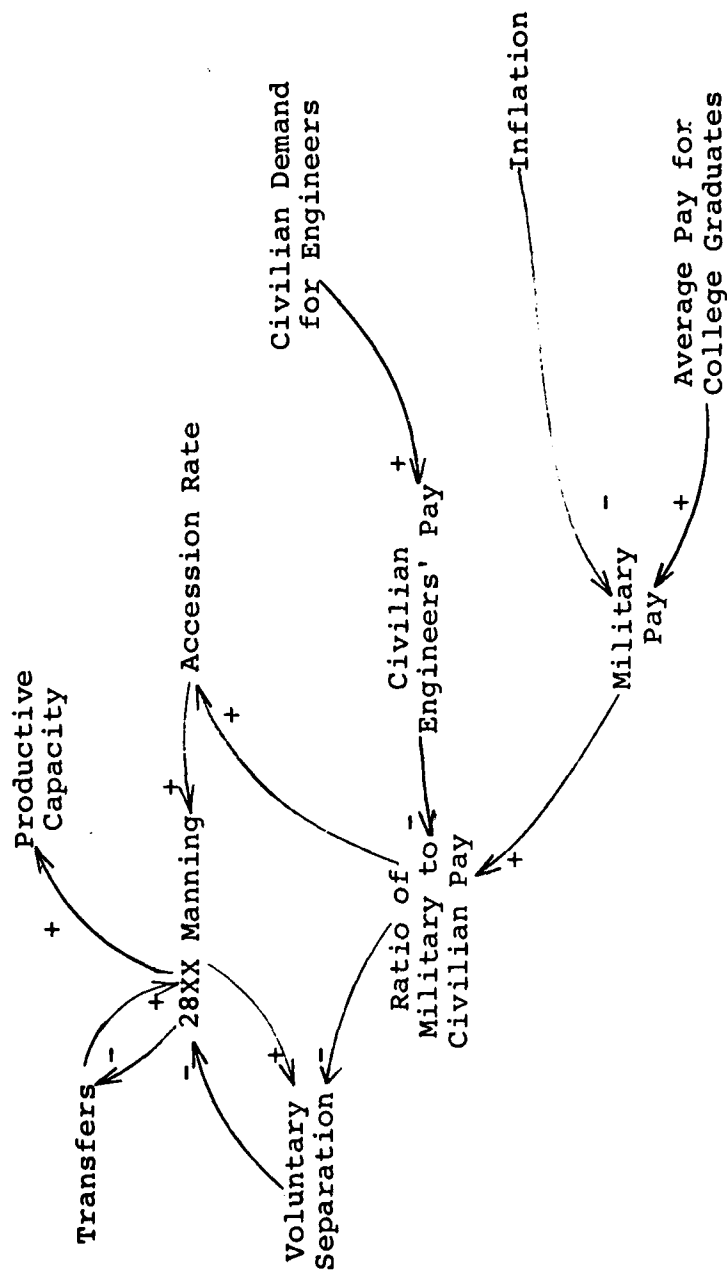


Fig. 37. Hypotheses Underlying the Model Causal Loop Diagram

salaries offered in the private sector for comparable positions and the need to curb inflation.

How each section of the System Dynamics model represents the corresponding aspect of the real system is described in detail in Chapter III. Following the detailed descriptions of the model, several sample runs are described to illustrate the potential application of the model. Although the detailed defense of the model structure is considered complete, more validation testing, sensitivity analysis, and data collection must be accomplished before the model can be used with a high degree of confidence.

Conclusion

Although additional effort would be required to perform a complete analysis of alternative compensation policies, this report presents a complete framework for such analyses. The 28XX officer responses to the Air Force Quality of Life Survey indicate that changes in compensation policies could potentially increase the retention of Development Engineer Officers. Certainly an analysis of alternative compensation policies is warranted.

The method employed to estimate the relationship between productive capacity and the numbers of Lieutenants, Captains, and Field Grade Officers provided reliable results. This method should be refined and the elicitation expanded to assess the validity of using this function to compare

the productive capacity of alternative Development Engineer Officer force projections.

If potential users of the System Dynamics model judge the detailed design of the model to be an adequate representation of the real Development Engineer Officer personnel system, more extensive validation of the model would be warranted. This additional model experimentation should be accomplished to test all aspects of the computer program and to identify the parameters for which more accurate estimates are required. When sufficiently accurate estimates of these sensitive parameters are developed, the model may be used to evaluate alternative proposals related to the retention of Air Force Development Engineering Officers.

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Appendix A
Compendium of Relevant Studies

Introduction

This annex has three purposes: (1) to provide a more in-depth review of the literature on engineering officer career motivation, (2) to indicate the basis for many of the generalizations mentioned in Chapter II, and (3) to assist readers in selecting readings for further study on the subject.

The following paragraphs provide extracts and a summarized description of some of the more pertinent reports analyzed during the literature review for this thesis. Each review focuses on those findings pertinent to engineering officer retention.

Several of the extracts are written with the assumption that readers have a basic understanding of statistical regression.

Extracts from Engineering Officer Studies

Improvement of the Procurement, Utilization, and Retention of High Quality Scientific and Technical Officers. Technical Report (Drysdale, 1968). This report reviews the results of many studies produced between 1958 and 1968. Pertinent studies were analyzed and responsible executives

were interviewed to identify the key issues which "express values held to be most important to scientific/technical personnel which are believed to be least available in Air Force service [Abstract]."

One of these studies (Downey, et al., 1964) analyzed a survey of "former students of the Air Force Institute of Technology (AFIT), some of whom had left the service [p. 7]."

Highly summarized results from this analysis are provided in Table A-I. In this table,

. . . the figures for IMPORTANCE and POSSIBILITY are the mean ratings given . . . for each of the items, on a scoring system in which importance was rated from "not important at all" (rated 1) to "extremely important" (rated 5), and possibility was rated from "none at all" (rated 1) to "very good" (rated 5) [p. 7]."

Obviously, those items that are considered to be most important and at the same time the least available in the Air Force, would if favorably changed, have the greatest leverage on decisions to seek, or to remain in, Air Force commissioned scientific/technical service [p. 7].

Since there is "no universally accepted formula . . . for determining the potential leverage based on these two considerations," Drysdale used the difference of the mean importance and possibility ratings, the ratio of these ratings, and the square of the mean importance rating divided by mean possibility rating as three different indicators of leverage. In general, higher values of any of these indicators imply greater leverage. Table A-I shows the factors with the higher leverage values in descending order of the difference indicator.

TABLE A-I
IMPORTANCE AND POSSIBILITY RATINGS AND RELATIONSHIPS SURVEY OF FORMER AFIT STUDENTS -
SAMPLE OF SCIENTIFIC OFFICERS (AFSCs 2XXX) (pp. 8,12)

Rank	Job Characteristic	Possibility	Importance	Mean Rated Values		
				Importance Minus Possibility	Importance/ Possibility	Importance ² / Possibility
1	Be promoted on the basis of ability	2.43	4.61	2.18	1.90	8.75
2	Consistent, intelligent personnel policies	2.40	4.37	1.97	1.82	7.95
3	Have a say in what happens to you	2.57	4.20	1.63	1.63	6.87
4	Advance at a fairly rapid rate	2.42	3.96	1.54	1.64	6.48
5	Have competent supervisors	3.03	4.55	1.52	1.50	6.83
6	Obtain a good salary	2.54	4.03	1.49	1.59	6.40
7	Be given recognition for work well done	3.07	4.35	1.28	1.42	6.15
8	Feel that you are accomplishing something	3.55	4.76	1.21	1.34	6.38
9	Make a lot of money	1.92	3.12	1.20	1.62	5.07

Drysdale also presented partial results from another survey of officers with less than five years' commissioned service at the Air Proving Ground Center (McAbee, et al., 1961). A summary of these data is presented in Table A-II in essentially the same format as the previous table, except that POSSIBILITY is replaced by SATISFACTION. The rating scale for the SATISFACTION responses was from 1 meaning "strongly dissatisfied" to 5 meaning "strongly satisfied." The IMPORTANCE responses ranged from 1 for "very unimportant" to 5 for "very important" (p. 7).

From the analyses and his discussions with responsible executives, Drysdale derived the following key issues which he judged to be "foremost in the minds of career decision-makers, namely the affected individuals [p. 21]."

1. Promotion on merit
2. Consistent, intelligent personnel policies
3. Voice in assignments
4. Competent supervisors
5. Fairly rapid advancement
6. Recognition for accomplishment
7. Good salary
8. A profession of military science.

Early in the study, Drysdale emphasized that "the vital need is for high quality, not large quantities, in the technical-officer ranks [p. 5]." Accordingly, his recommendations focused upon actions designed to attract and retain the high quality officers. Later he noted that,

TABLE A-II

MEAN VALUES OF SATISFACTION AND IMPORTANCE RATINGS OF JOB CHARACTERISTICS, AND THEIR
 RELATIONSHIP - AIR PROVING GROUND CENTER SURVEY - SCIENTIFIC/ENGINEERING OFFICER
 (AFSC 25XX-57XX) SAMPLE (pp. 13, 14)

Rank	Job Characteristic	Mean Rated Values			
		Satisfaction	Importance	Importance Minus Satisfaction	Importance ² / Satisfaction
1	Promotion	2.2	4.6	2.3	2.09
2	Utilization	2.4	4.8	2.4	2.00
3	Pay	2.1	4.3	2.2	2.03
4	Assignment	3.2	4.6	1.4	1.44
5	Officer Effectiveness Reports	2.8	4.1	1.3	1.47
6	Housing	3.0	4.3	1.3	1.43
7	Prestige	3.3	3.9	0.6	1.18
8	Leadership	3.9	4.4	0.6	1.13
					9.61
					9.60
					8.72
					6.61
					5.96
					6.16
					4.61
					4.96

"It must be remembered, however, that actions favorable to personnel of high quality are often unfavorable to mediocre or low quality personnel [pp. 35-36]."

Drysdale argues that the most effective way to improve procurement, utilization and retention of high quality technical officers is to focus upon the key issues identified above. In light of these issues, he recommended that,

1. A clear distinction be made between the careers of R&D SCIENTIST and R&D MANAGER [p. 36]. The main matter to which this recommendation is addressed is that of maintaining consistency in the required qualifications for scientific and technical officers and in their utilization, and in solving the problems of procuring and retaining the qualified scientific and technical officers that are required for such utilization [p. 38].

2. A scientific grade structure be established for Air Force scientific and technical officers to be used as an indicator of scientific status, and in appropriate composites with military rank, for determination of position and total compensation. . . . The scientific grade of an individual would be set by his qualifications of education, experience, past achievements, and manner of performance of scientific work. . . .
. . . The "regular compensation" of all individuals would be governed by the higher of the two levels that [he] possesses [grade or rank], not a combination of the two. . . . The regular compensation available for superior scientific quality would . . . be competitive with Civil Service and industry [pp. 44-45].

3. A three-element entry and promotion system based on merit be established. . . .
. . . The three elements of the proposed entry and promotion system are the inputs of (a) the affected individual, (b) his actual or potential supervisor, and (c) the institutional review and action body. . . .
. . . It would be expected that scientific grade promotion would be faster in the R&D SCIENTIST field, and military rank promotion would be faster in the R&D MANAGER field, but no fixed rule would exist in this regard. . . [pp. 48-50].

4. A system be established which employs the exercise of judgement and choice by job supervisors, potential job incumbents, and institutional action bodies on each scientific/technical officer assignment.

Drysdale recognized "the growing enlightenment on the subject" and assumed efforts to improve the assignment process would continue (p. 52). And finally,

5. "A Military Scientist career field be established." Military Science was defined as

. . . systematized knowledge of the nature and means of military influence, their relations to other means, and to the subjects, objects, and objectives of influence on behalf of national interest.

An Investigation of the Factors Which Affect the Career Selection Process of Air Force Systems Command Company Grade Officers. Air Force Institute of Technology Thesis. (Moshbach and Scanlan, 1979). Major Mosbach and Captain Scanlan developed a model to predict career intent based upon perceived attraction of Air Force versus Civilian career alternatives, expectations of family members, and current job satisfaction. To test this model, they developed a survey which was completed by 2200 company grade officers in Air Force Systems Command. The survey asked each respondent to indicate his intent to make the Air Force a career. This survey also included questions about 11 different outcomes of choosing a career. The respondents were asked to rate the desirability of each outcome and the extent of association of this outcome with an Air Force career. The products of these two responses

for each outcome were used as the independent variables for a stepwise regression with career intent as the dependent variable to determine the relative significance of the different outcomes. Their analysis of the total sample led them to conclude:

1. Family opinion, particularly that of the spouse, is of major importance to the career selection decision, especially during the first six years of an individual's career.
2. Job challenge is particularly important to officers from commissioning to about five years. At that point, utilization of training and abilities becomes the dominant factor.
3. Enforcement of standards has a strong negative association during the years immediately preceding career decision points prior to promotion to Captain and promotion to Major.
4. High salary and the 20-year retirement were not particularly significant, but the concern expressed by the majority of respondents who made comments indicated this could change depending on Presidential and Congressional actions in these areas.
5. The "up or out" policy had no practical association with career decisions of the total sample.

One should interpret these conclusions in light of their survey instrument, particularly with respect to the significance of salary. The survey asks respondents to rate the desirability of "earning a high salary [p. 115]" without specifically defining "high salary." From their results one can conclude that the prospect of a "high salary" was not a significant explanatory factor in career intent. However, based upon their data, one cannot conclude that a "low salary" or "at least a moderate" salary would not be a significant factor.

Of more direct interest was Mosbach's and Scanlan's analysis of the development engineer (Air Force Specialty

Code 28XX) subgroup of their sample. This analysis was completely analogous to that performed on the entire group; i.e., stepwise regression with career intent for the criterion variable and the products of the desirability and attainability ratings of the 11 outcomes for the independent variables. The results of this analysis for the 730 development engineer responses are depicted in Table A-III. Although the results were not discussed in the Mosbach and Scanlan thesis, it is easy to note the paramount importance of effective utilization of engineers' abilities and training. Similarly, one can conclude that family opinion, job challenge, relocation, enforcement of standards and the retirement program all have a moderate effect on career intent. After taking these six most significant factors into account, promotion opportunity, "up-or-out" policies, family separations, recognition, and "high salary" are relatively insignificant factors in career motivation of engineers.

Another interesting aspect of the Mosbach and Scanlan survey is that respondents were asked to estimate probabilities of success related to an Air Force or civilian career. The results depicted in Table A-IV demonstrate the so-called "grass is greener" phenomenon. From this table it appears that almost all the respondents felt they had a better than even chance of obtaining at least as good a job on the outside as they can in the Air Force. And, on

TABLE A-III
SUB-SAMPLE REGRESSION/CORRELATION VALUES OF CAREER INTENT WITH
AIR FORCE INSTRUMENTALITY/VALENCE PRODUCTS (28XX SAMPLE) (pp. 89,142)

Step	Outcome	F to Enter	Multiple R	Simple Correlation with Career Intent
1	Effective use of abilities and training	107.27	.36	.36
2	Favorable attitude on the part of spouse or immediate family regarding career	44.88	.42	.31
3	An interesting, challenging job	24.13	.45	.34
4	Relocations every four years or less	21.00	.48	.27
5	Set of rules and regulations governing behavior	11.74	.49	.28
6	Twenty-year retirement	7.60	.50	.21
7	Promotion based on job performance	3.54	.50	.28
8	The requirement to attain positions of increased rank and responsibility in order to remain a member of the organization	2.39	.50	.10
9	Extended separation from family and friends	.88	.50	.07
10	Recognition of achievement and accomplishment	.54	.50	.22
11	Earning a high salary	.50	.51	.15

TABLE A-IV

DESCRIPTIVE STATISTICS FOR EXPECTANCY TERMS (pp. 74,119)

Question ("What do you think is your chance of being . . .")	Mean (All Responses)	Standard Deviation
selected for promotion to Major	79.2%	24.3%
hired in a civilian position . . . comparable with your present job	87.3%	17.6%
able to complete 20 years of service in the Air Force	81.0%	22.7%
able to . . . attain a posi- tion at least equivalent . . . to an Air Force middle manager (0-4 or 0-5) within 20 years	89.1%	14.6%

average, they perceived the prospects of success in a civilian career as being greater than that in the Air Force.

Relationship Between Productivity, Satisfaction, Ability, Age, and Salary in a Military R&D Organization.

Research article. (Vincent and Mirakhor, 1972).

Data derived from the questionnaire completed by 94 salaried scientists and engineers engaged in research and development activities at the U.S. Army Missile Command indicate that personnel with the highest job satisfaction are the most productive [p. 51].

As measured by the number of papers published, patents disclosed, and presentations made. Two dramatic examples of this relationship between job satisfaction and

productivity are given: scientists and engineers in the 15,000 to 19,000 annual salary range (in 1972) who indicated they liked their job "very much" produced twice as many papers as those who liked their job "less than very much [pp. 45,48]." And in this same salary range the highly satisfied employees produced almost four times more patents than their low satisfaction counterparts.

These data support the hypothesis that the effective utilization of scientists and engineers is dependent on a work environment which successfully produces high job satisfaction [p. 51].

The scientists and engineers were asked to indicate both the ten features most and ten features least important to their job satisfaction. The results are given in Tables [A-V] and [A-VI] [p. 46].

This article also gives a pertinent quote attributed to Vroom.

. . . job satisfaction is closely affected by the amounts of rewards that people derive from their job, and . . . levels of performance is closely affected by the basis of attainment of rewards. Individuals are satisfied with their jobs to the extent to which their jobs provide them with what they desire, and perform effectively in them to the extent that effective performance leads to attainment of what they desire.

How Can the Retention Rate of Scientific and Development Engineering Officers Be Increased? Air Command and Staff College Thesis. (Winchell, 1965). Based upon projections from the Bureau of Labor, Major Winchell forecasted that a deficit in Scientific and Engineering officers would exist today. To avoid the deficit, he recommended that officers in Air Force Specialty Codes 26XX,

TABLE A-V

TEN MOST IMPORTANT JOB FEATURES (p. 46)

Rank		Number
1	Pay	43
2	Challenge of assignments	34
3	Nature of assignments (variety, monotony)	34
4	Opportunity to use initiative	31
5	Graphical location	28
6	Job security	27
7	Promotion prospects	17
8	Opportunity to accept responsibility	16
9	Opportunity for professional development	13
10	Opportunity to see ideas applied	13

TABLE A-VI

TEN LEAST IMPORTANT JOB FEATURES (p. 46)

Rank		Number
1	Status in community	41
2	Public attitude to my work	33
3	Paper work	33
4	Writing and signing any reports and correspondence	32
5	Security restrictions to publication	30
6	Holidays	25
7	Hours of work	23
8	Technical staff support	14
9	Opportunity to work on highly engineered products	11
10	Physical condition of work (noise, lighting, heating)	11

27XX, and 28XX be granted a "special pay amounting to \$100 per month following their fourth year of service." The study indicates that the rank and pay incentives offered military doctors were effective in substantially reducing their attrition rate through 1963. Major Winchell supports his recommendation by explaining that scientific and engineering officers are similar to physicians, dentists, and lawyers. "All are highly educated specialists who would enjoy higher pay and professional status in the civilian community, and all present a serious retention problem." Therefore, he argues a scientific and engineering bonus could be justified and effective in retaining the technical officers needed by the Air Force.

Extracts Of Officer Retention Studies

Structure, Environment, and Satisfaction: Toward a Causal Model of Turnover From Military Organizations.
Research article. (Bluedorn, 1979). "An extensive search of the literature on military and civilian turnover revealed 60 studies . . . relevant to four propositions [p. 186]:"

Proposition 1. The greater the pay, the lower the propensity to leave the organization [p. 184].

Proposition 2. The more negative the reaction to total organization control, the greater the propensity to leave the organization [p. 184].

Proposition 3: The greater the environmental push (as measured by indicators of how the draft influenced each survey respondent's decision to enter the service) at the time an organization is joined, the greater the propensity to leave the organization [p. 185].

[And] proposition 4: The greater the environmental pull (as measured by the respondent's comparisons of military and civilian work with respect to eight different qualities), the greater the propensity to leave the organization [p. 185].

Bluedorn hypothesized that the factors related to each of these propositions combined to determine job satisfaction which in turn determined turnover intention (voluntary separation). This model was tested using responses by 6,156 Army officers to a National Opinion Research Center survey conducted in 1964. Bluedorn's results are shown in Table A-VII. In addition to the variables mentioned above, Bluedorn included five biographical variables (which he called correlates), to test whether or not all determinants were included in the model. Bluedorn's results supported each proposition and provided a model of military turnover intention which is the best currently available in terms of parsimony (only 5 independent variables) and explanatory power (explaining 65 percent of the variance in turnover intention).

Taking the total causal effect of the variables as an index of their relative importance in producing turnover, the variables rank as follows: environmental pull, satisfaction, pay, environmental push, and organizational control [p. 194].

In spite of the last place ranking of organizational control, Bluedorn warns that

. . . it would be premature to disregard organizational control as a major cause of turnover, particularly in military organizations, until it has received additional testing with a better operationalization.

TABLE A-VII

STANDARDIZED REGRESSION COEFFICIENTS FROM MULTIPLE
REGRESSIONS WITH AND WITHOUT THE CORRELATES^a (p. 198)

Determinants	Dependent Variable			
	Satisfaction		Turnover Intentions	
	D Only ^b	With C ^c	D Only ^b	With C ^c
Environmental Push	-.17	-.16	.10	.09
Environmental Pull	-.44	-.40	.28	.22
Organizational Control	-.16	-.15	.02	.00
Pay	.20	.03	-.27	-.04
Satisfaction	--	--	-.41	-.36
<u>Correlates</u>				
Length of Service (\log_{10}) ^d		.18		-.35
Age (\log_{10}) ^d		.06		.01
Education		.03		.00
Marital Status		-.01		.03
City Size at Birth		.01		.01
Explained Variance (Adjusted R^2)	.45	.47	.65	.70

^a Coefficient with absolute values less than .10 were not regarded as significant.

^b Multiple regression with determinants only.

^c Multiple regressions with correlates added after the determinants.

^d Age and Length of Service were transformed logarithmically to improve the linearity of their relationships with Turnover Intentions.

Among the biographical variables studied, only length of service significantly increased the amount of explained variance (from 65 percent to 70 percent). This

. . . significant increase in explained variance indicates that there are other determinants which should be included in the model. Discovering these determinants is a task for future research. . . [p. 197].

Although the model presented in this article is exceptional for Army officer retention, Bluedorn makes one comment which should cause us to question its relevance for Air Force engineer officer retention.

A possible explanation for the unusually high amount of variance explained by . . . the present research is that [the study] examined turnover in [an organization] in which turnover involved, for most practical purposes, leaving both an organization and an occupation [p. 199].

Intuition and other research (Assistant Secretary of Defense, 1967) indicate that most Air Force engineering officers, as distinguished from other military officers, do continue in their occupation after separating from the Air Force.

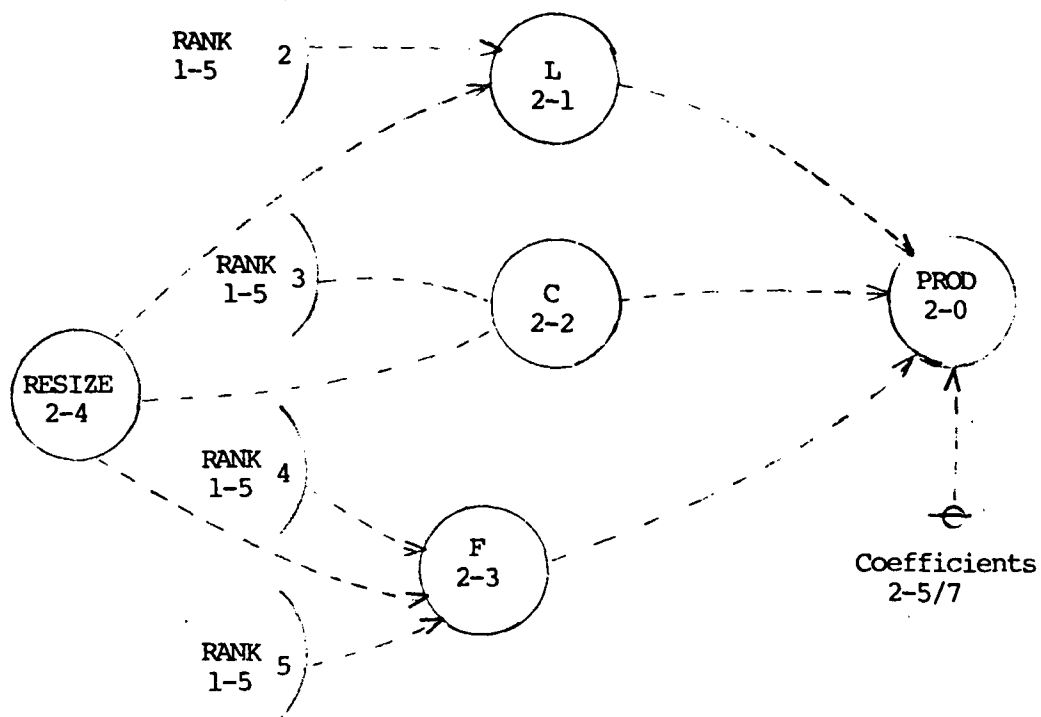
A Look at Junior Officer Retention. Air Command and Staff College. Research study. (Richard, 1972). Writing prior to the advent of the All-volunteer Force, Major Richard indicated that "the retention efforts of the U.S. Air Force must be improved" His study "presents background on the all-volunteer force and describes the present [1972] anti-militaristic feeling in the United States [Abstract]." He identifies two major causes for this

anti-militarism: the Vietnam War and bad publicity received by the military (for example, newspaper reports of cost overruns on weapon system acquisitions). Although the impact of this adverse sentiment is hard to determine, the decreased prestige of the Military services must have an adverse effect on retention (pp. 12-13).

Major Richard also provides an excellent summary of two motivational theories relevant to retention policies: Maslow's Hierarchy of Needs and Herzberg's Two-Factor Theory. He then describes how these concepts were used by the Air Force in conducting the Officer Motivation Study "New View" (1966) and in formulating the career motivation programs established in Air Force Manual 35-16, USAF Career Motivation Program for Officers and Airmen; Air Force Manual 36-23, Officer Career Management, and the USAF Personnel Plan. Based upon his examination, Major Richard concludes that the Air Force's retention "programs are excellent and retention would be vastly improved if these programs were carried out [Abstract]" and that "the general lack of interest displayed by [commanders and supervisors] is the primary cause for the unsuccessful Air Force retention effort [p. 50]."

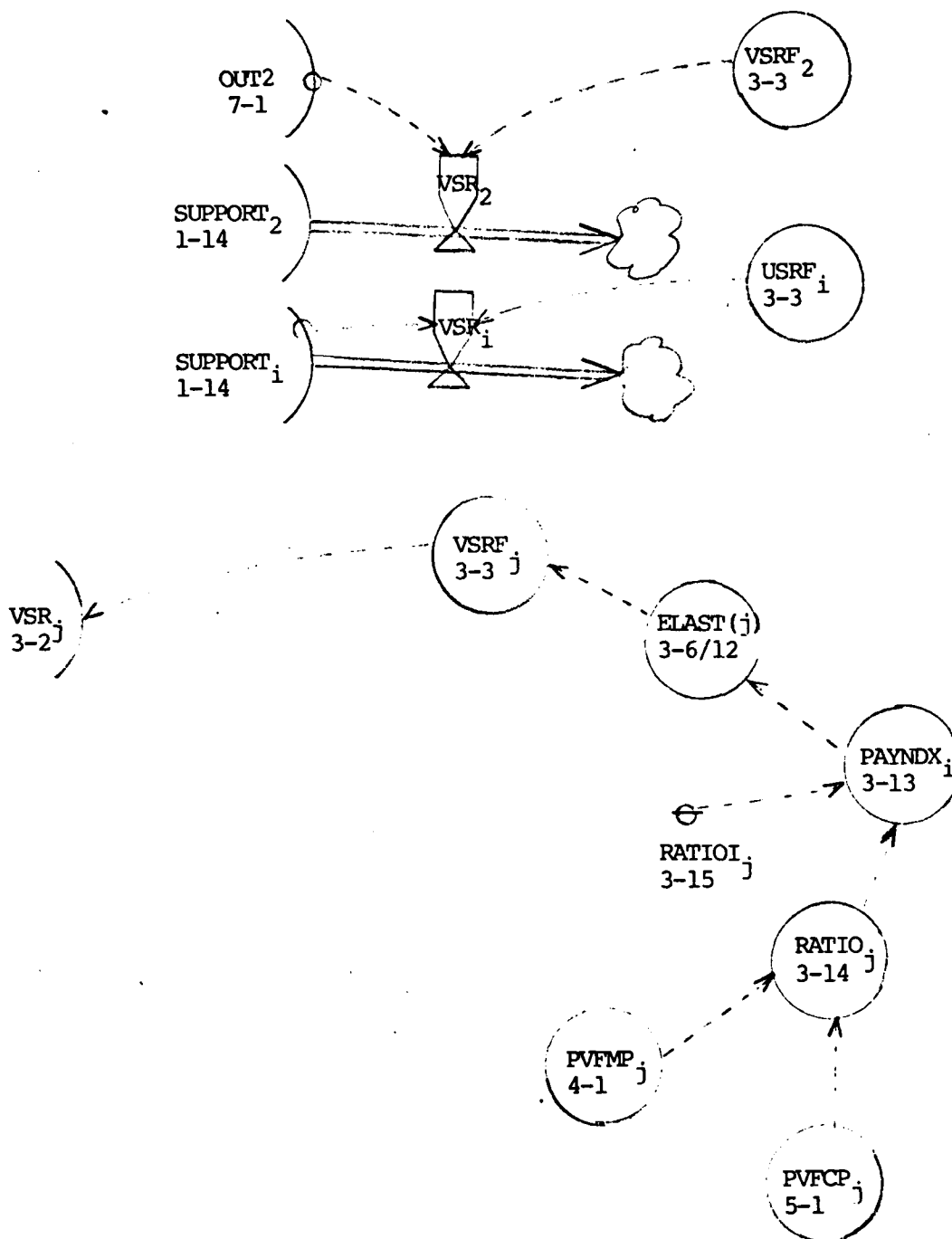
Appendix B
Model Flow Diagram and Equations

Flow Diagram

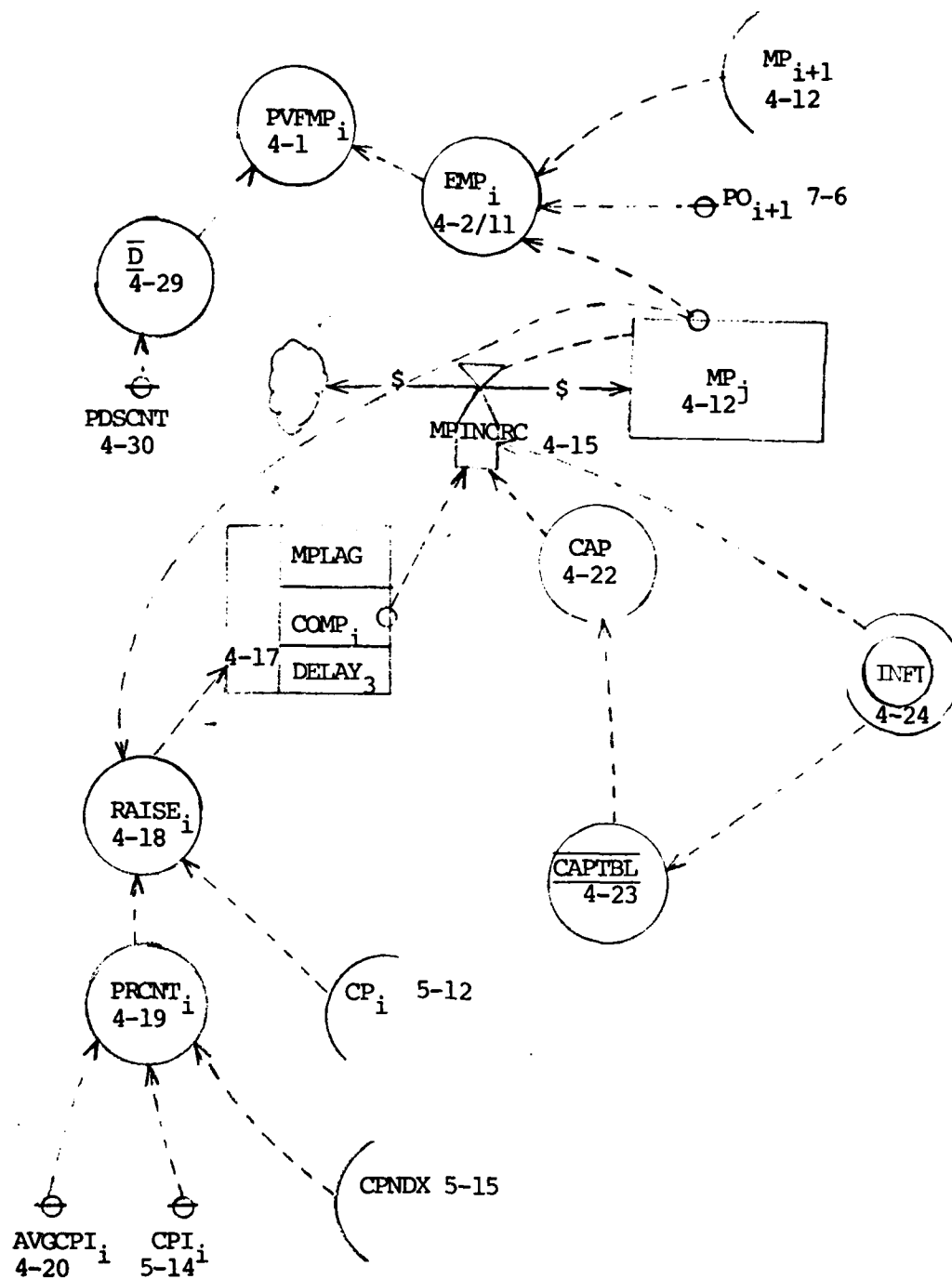


Section 2: Productive Capacity

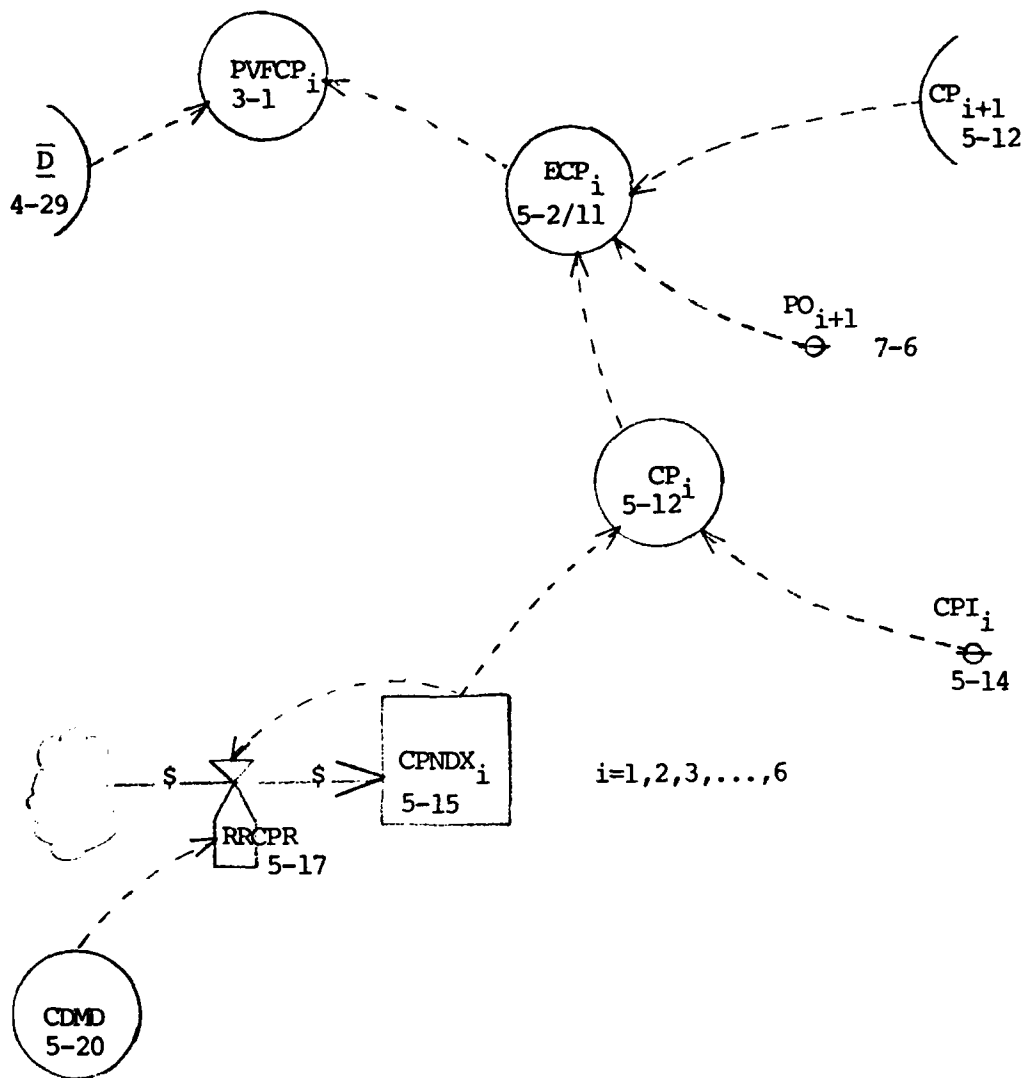
Note: The flow diagram for manpower levels is depicted in Figure 7 on page 59.



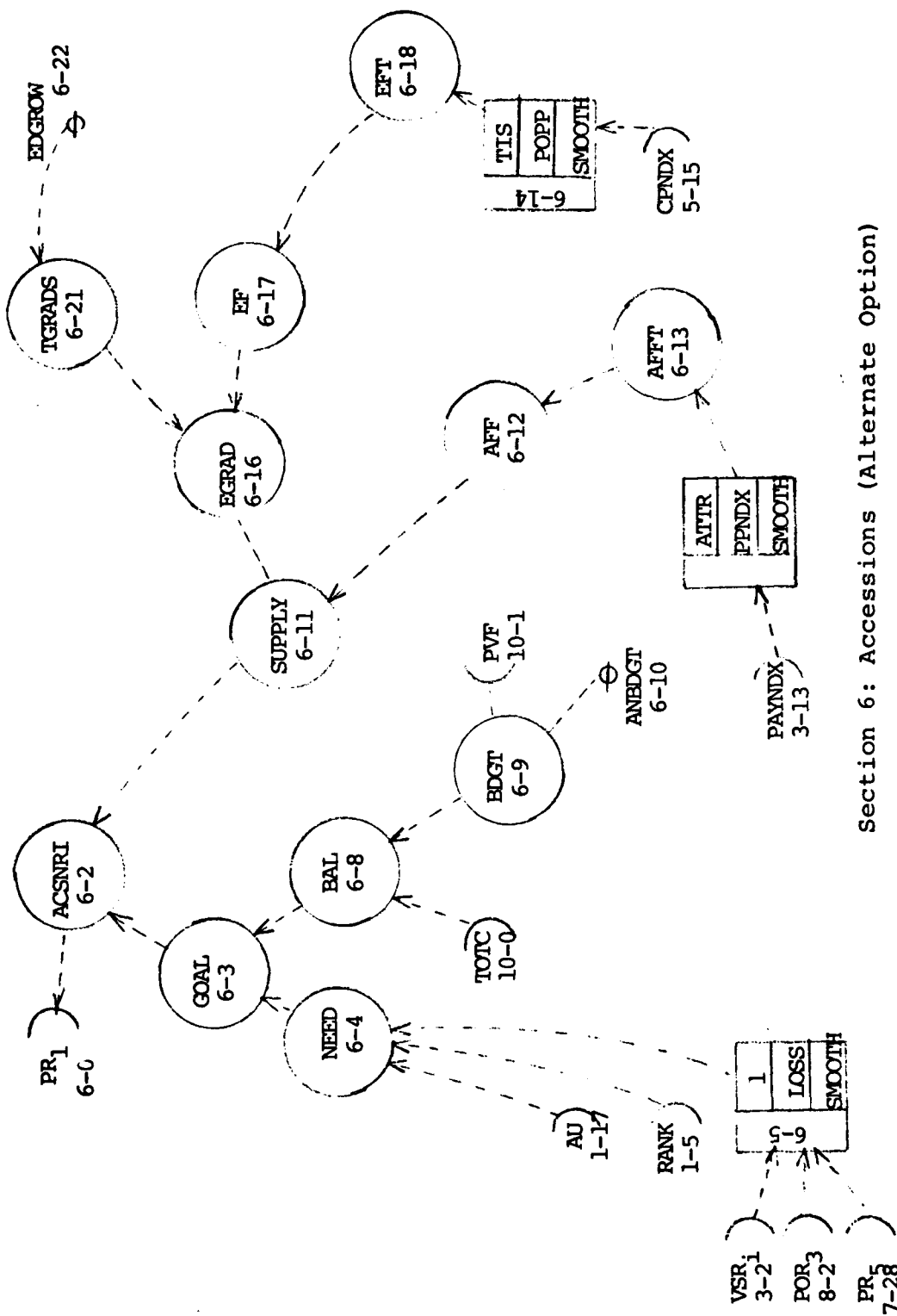
Section 3: Voluntary Separations (Alternative Options)



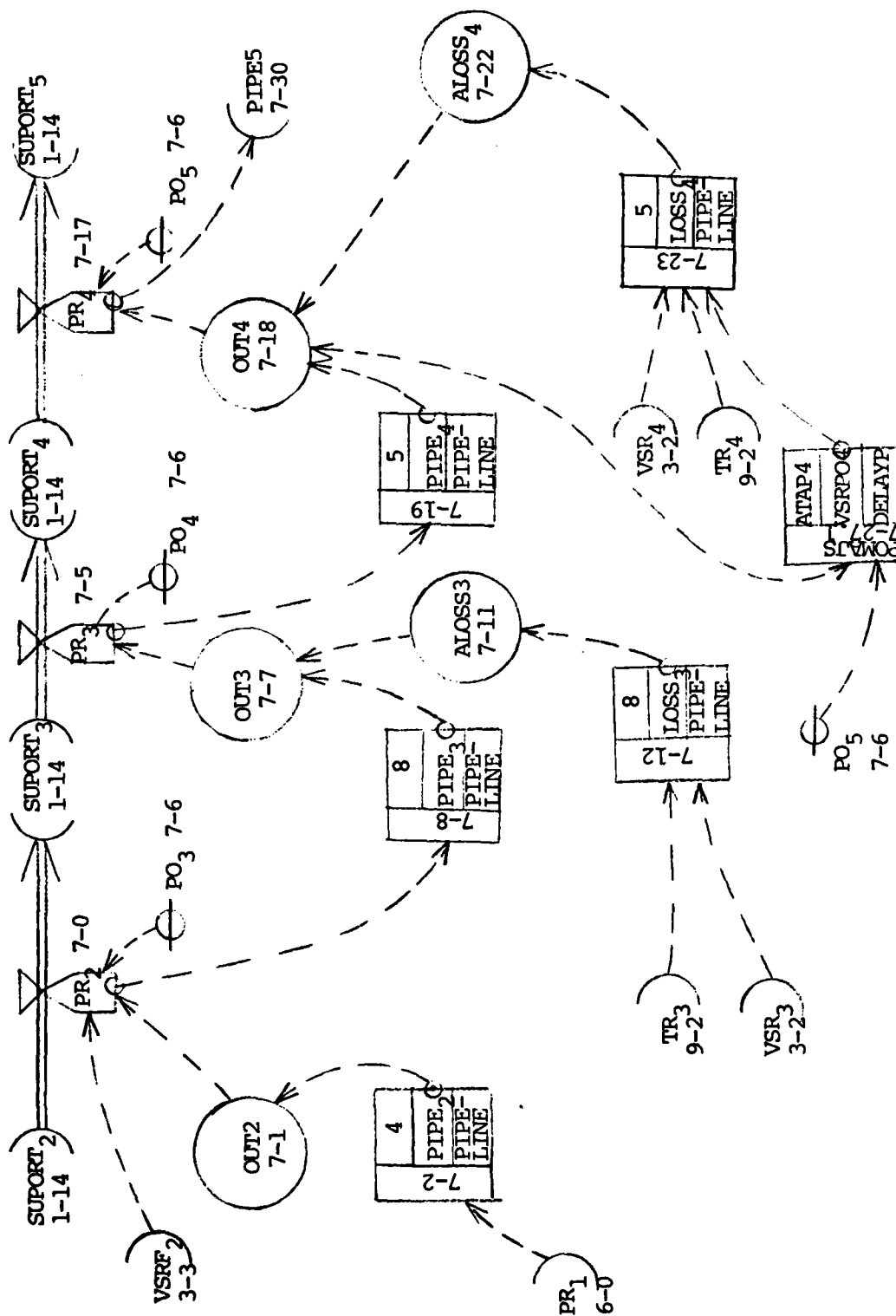
Section 4: Military Pay

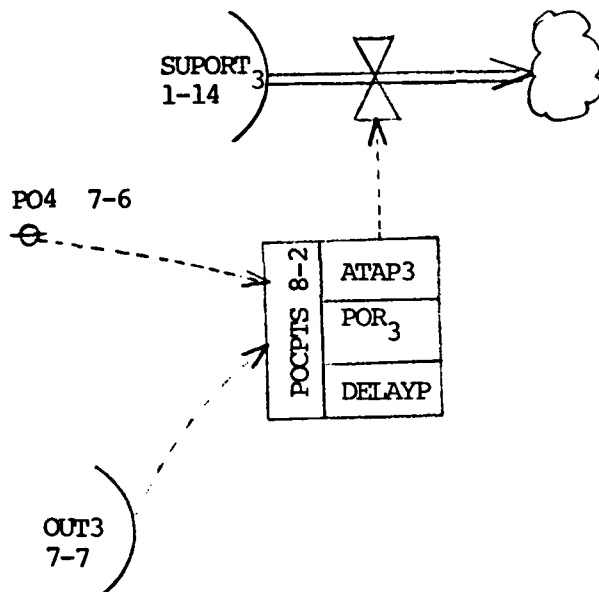


Section 5: Civilian Pay

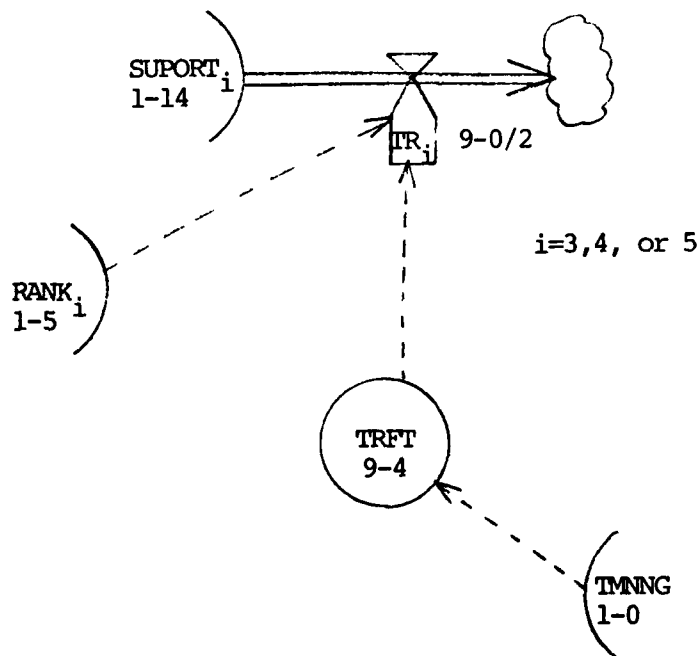


Section 6: Accessions (Alternate Option)

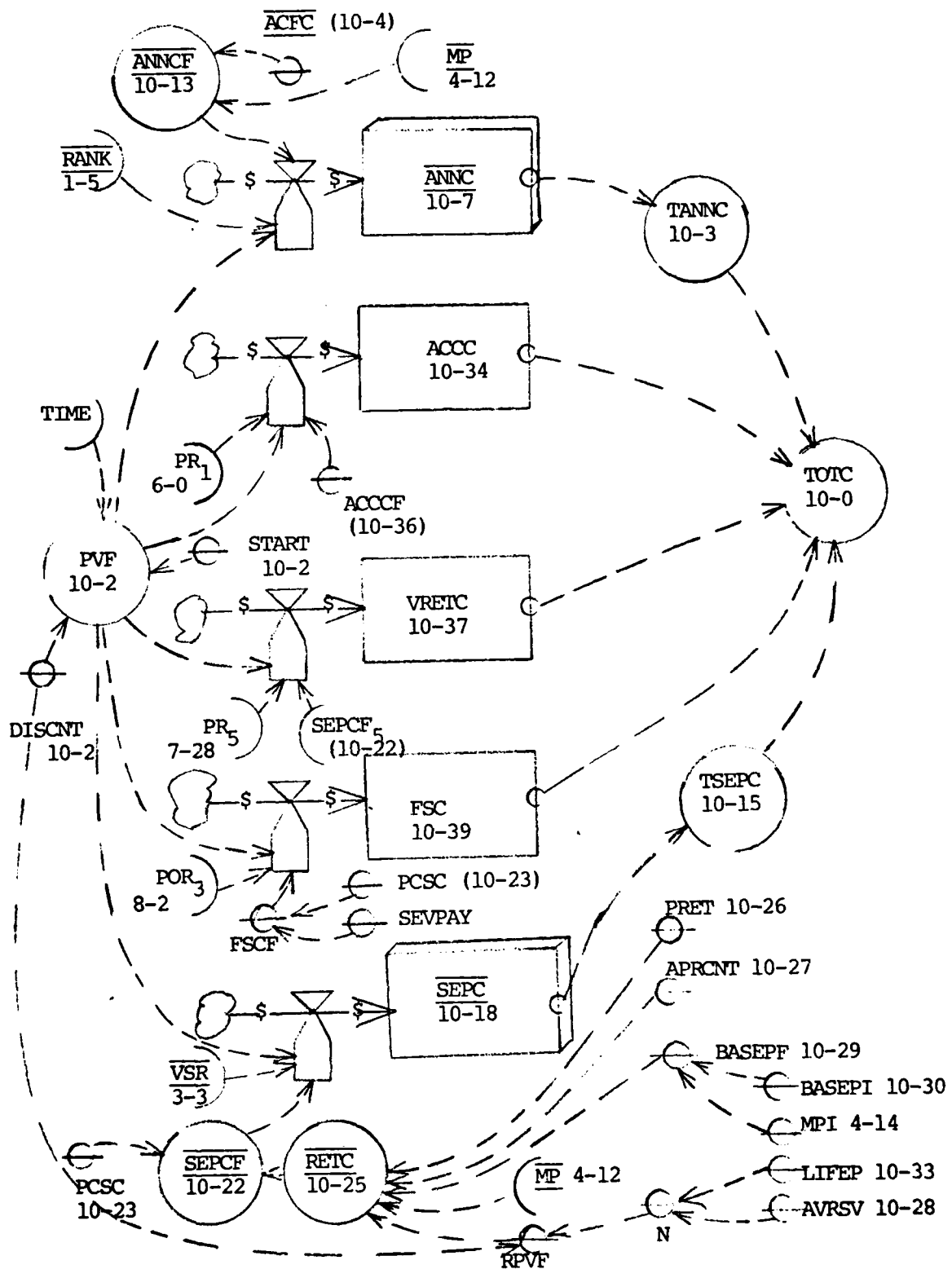




Section 8: Separations Due to Passovers



Section 9: Transfers



Section 10: Cumulative Costs

NOTE START TIME

```

N TIME=START 3-1
C START=1998.75 3-2

```

NOTE FOR VARIABLES

FOR 1/1705=1/5, 1/1706=2/5, 1/1707=3/5, 1/1708=4/5, 1/1709=1/6, 1/1710=1/2, 1/1711=3/4
X 1/1712=1/6, 1/1713=1/4, 1/1714=1/3, 1/1715=4/6, 1/1716=1/5, 1/1717=1/5
X 1/1718=5/6, 1/1719=2/4, 1/1720=1/4 0-2

INXOY	INDEX FROM RANK 0-X TO RANK 0-Y (INTEGER)	4-0
INXOY	INDEX FOR YEARS FROM X TO Y (INTEGER)	0-0

NOTE SECTION 1: PAPER LEVELS

```

A TRNGG:=TRANK,K/50*(AU,K) 1-0
A TRNGG,K(1)=2 1-1
A RANK,K(I2T05)=RANK,K(I2T05)/AU,K(I2T05) 1-2
A TRANK,K=50*(RANK,K) 1-3
A RANK,K(1)=0 1-4
A RANK,K(I2T05)=RTDSP,K,K(I2T05)+SUPRT,K(I2T05) 1-5
A RTDSP,K=50*(RTDSP,K) 1-6
A RTDSP,K(1)=0 1-7
A RTDSP,K(I2T05)=RTDSP,I(I2T05-1)+
X TAP*L(RTDSPT,TIME,K)/952.75/(901.75+1) 1-8
T RTDSPT=0/184/84/14 1-9
T RTDSPT=1/54 1-10
A TSUPRT,K=50*(SUPRT,K) 1-11
L SUPRT,K(1)=SUPRT,K(1)-DT*TR,JK(1) 1-12
N SUPRT(1)=0 1-13
L SUPRT,K(I2T05)=SUPRT,J(I2T05)+DT*(TR,JK(I2T05)-
X VSR,JK(I2T05)+PR,JK(I2T05-1)-PR,JK(I2T05)-PR,JK(I2T05)) 1-14
N SUPRT(I2T05)=SUPRT,I(I2T05-1) 1-15
T SUPRT=1011/1225/715/386 1-16
A AU,K(I1T05)=AUTHI(I1T05)*(1+RAMP(AUGROW,START)) 1-17
T AUTHI=2/535/2362/935/563 1-18
C AUGROW=0 1-19

```

TMNNG	TOTAL MANNING (PERCENT OF TOTAL AUTHORIZED) 1-2	
	STRENGTH	
MNNG(I)	MANNING IN GRADE I (PERCENT OF AUTHORIZED	1-
TRANK	TOTAL ASSIGNED (OFFICERS)	1-3
RANK(I)	ASSIGNED IN RANK I (OFFICERS)	1-5
RTDSUP	TOTAL RATED SUPPLEMENT (OFFICERS)	1-6
RTDSUP(I)	RATED SUPPLEMENT IN RANK I (OFFICERS)	1-8
RTDSUP(I)	INITIAL RATED SUPPLEMENT IN RANK I	1-9
	(OFFICERS)	
TSUPRT	TOTAL SUPPORT (NON-RATED) (OFFICERS)	1-11
SUPRT(I)	SUPPORT IN RANK I (OFFICERS)	1-13
SUPRT(I)	INITIAL SUPPORT IN RANK I (OFFICERS)	1-16
TR(I)	NET TRANSFER RATE (INTO+, OUT-) FOR	9-8/1
	RANK I (OFFICERS/YR)	
VSER(I)	VOLUNTARY SEPARATION RATE FROM RANK I	9-1
	(OFFICERS/YR)	
PR(I)	ACCESSION RATE (PROMOTION TO 2LT) (OFFICERS/YR)	6-2
PR(I)	PROMOTION RATE FROM RANK I (FOR 1-2 TO 5)	7-3
	(OFFICERS/YR)	
FOR (I)	PASSIVE SEPARATION RATE (OFFICERS/YR)	8-8/5
AU(I)	AUTHORIZATIONS IN RANK I (BILLETS)	1-17
AU(I)	INITIAL AUTHORIZATIONS IN RANK I (BILLETS)	1-18
AUGROW	GROWTH RATE OF AUTHORIZATIONS (BILLETS/YR)	1-19

NOTE SECTION 2: PRODUCTIVE CAPACITY

```

A PROD,K=AO+A1*F,K+A2*F,K*O,K+A3*(F,K**2)+
X 44*(L,K**2)*(O,K**2)+
X 45*(O,K**2)+A6*O,K+
X 47*L,K*O,K**2) 2-8
A L,K=RANK,K(2)*RESIZE,K 2-1
A O,K=RANK,K(3)*RESIZE,K 2-2
A F,K=(RANK,K(4)+RANK,K(5))*RESIZE,K 2-3
A RESIZE,K=180/8.* (O,K) 2-4
C AO=-159.51829;A1=12.91364;A2=.03101887 2-5
C A3=-.2196564;A4=.6153668E-3;A5=-.4124823E-2 2-6
C A6=2;A7=0 2-7

```

PROD	PRODUCTIVE CAPACITY (PERCENT OF COMPLETE MISSION)	2-8
L	1TS IN "AVERAGE" ORGANIZATION (OFFICERS)	2-1
O	CAPTS IN "AVERAGE" ORGANIZATION (OFFICERS)	2-2
F	FIELD GRADE OFFICERS IN "AVERAGE" ORGANIZATION (OFFICERS)	2-3
RANK(I)	ASSIGNED IN RANK I (OFFICERS)	1-5
RESIZE	"FAIR SHARE" OF TOTAL OFFICERS ASSIGNED FOR EACH "AVERAGE" ORGANIZATION (PERCENT)	2-4

NOTE SECTION 3: VOLUNTARY SEPARATIONS

```

R VSR,KL(1)=0
R VSR,KL(2)=VERF,K(2)*OSTZ,K 3-1
R VSR,KL(1:105)=VSRF,K(1:105)*SUPRT(1:105) 3-2
A VERF,K(1:105)=SWITCH(VSRF2,1:105),VERF1,K(1:105),VSROPT) 3-3
C VSROPT=1 3-4

```

NOTE INITIAL VSR OPT

```

T VSRF2=0/.04/.07/.06/.15 3-5

```

NOTE ALTERNATE VSR OPTION

```

A VERF1,K(1)=0 3-4.1
A VERF1,K(2)=TABLT(ELAST2,PAYNDX,K(2)),.0,1.1,.05) 3-5
T ELAST2=.99/.95/.99/.81/.71/.51/.41/.34/.27/.21/.15/.09/.04/.01 3-6
A VERF1,K(3)=TABLT(ELAST3,PAYNDX,K(3)),.05,1.15,.05) 3-7
T ELAST3=.20/.14/.13/.07/.04/.02/.01/.01 3-8
A VSRF1,K(4)=TABLT(ELAST4,PAYNDX,K(4)),.0,1.2,1.1) 3-9
T ELAST4=.35/.27/.26/.035/.049 3-10
A VSRF1,K(5)=TABLT(ELAST5,PAYNDX,K(5)),.6,1.4,1.2) 3-11
T ELAST5=.20/.23/.10/.14/.15 3-12

```

```

A PAYNDX,K(1:105)=RATIO,K(1:105)/RATIO1(1:105) 3-13
A RATIO,K(1:105)=PVFMP,K(1:105)/PVFOP,K(1:105) 3-14
A RATIO1(1:105)=RATIO(1:105) 3-15

```

VERF(1)	ASSUMED STATIC VOLUNTARY SEPARATION RATE FACTOR (PERCENT/YR)	3-5
VSR(1)	VOLUNTARY SEPARATION RATE FROM RANK 1 (OFFICERS/YR)	3-1
VSROPT	VOLUNTARY SEPARATION RATE OPTION (3 FOR VSR=VSR2 OR 1 FOR VSR=VSR1)	3-2
VSRF	VOLUNTARY SEPARATION RATE FRACTION (PERCENT/YR)	3-5/11
SUPRT(1)	SUPPORT IN RANK 1 (OFFICERS)	1-10
PAYNDX	PAY INDEX (DIMENSIONLESS)	3-10
RATIO	RATIO OF FVMP TO FVOP (DIMENSIONLESS)	3-14
PVFMPI	PRESENT VALUE OF FUTURE MILITARY PAY EXPECTED BY THE AVERAGE OFFICER OF RANK 1 (\$)	4-1
PVFOP(1)	PRESENT VALUE OF FUTURE CIVILIAN PAY EXPECTED BY THE AVERAGE OFFICER OF RANK 1 (\$)	5-1

NOTE SECTION 4: MILITARY PAY

```

A PVEMP,K(I1T05)=SOLPRD(EMP,K(I1T05,*),1+6+D,1) 4-1
A EMP,K(1,J1T02)=EMP,K(1) 4-2
A EMP,K(1,J3T04)=EMP,K(2) 4-3
A EMP,K(1,J5T06)=0 4-4
A EMP,K(2,J1T02)=EMP,K(3) 4-5
A EMP,K(3,J1T04)=EMP,K(3) 4-6
A EMP,K(3,J5T06)=FO(4)*P,K(4)+(1-FO(4))*P,K(3) 4-7
A EMP,K(4,J1T02)=EMP,K(4) 4-8
A EMP,K(4,J5T06)=FO(5)*P,K(5)+(1-FO(5))*P,K(4) 4-9
A EMP,K(5,J1T02)=EMP,K(5) 4-10
A EMP,K(5,J4T04)=FO(6)*P,K(6)+(1-FO(6))*P,K(5) 4-11
L EMP,K(I1T06)=P,K(I1T06)-DT*MPINCR,K(I1T06) 4-12
N MP(I1T06)=MP(I1T06) 4-13
T MPI=14731/19711/24388/29409/35347/43911 4-14
R MPINCR,K(I1T06)=MPI*P,K(I1T06) 4-15
A MPINCR,K(I1T06)=MIN(COMP,K(I1T06),CAP,K-INVFL,K) 4-16
A COMP,K(I1T06)=DELAYO(RAISE,K(I1T06),MPLAC) 4-17
A RAISE,K(I1T06)=1-KO,K(I1T06)+CP,K(I1T06)-
X MP,K(I1T06)/P,K(I1T06) 4-18
A PRONT,K(I1T06)=AVGOPI(I1T06)/PI(I1T06)/CP*DY,K 4-19
T AVGOPI=17937/13671/29416/36666/47857/58178 4-20
C MPLAC=1 4-21
A CAP,K=TEXT(CAPTBL,INFL,K+0,2,1) 4-22
T CAPTBL=.27,27,15 4-23

A INFL,K=AINFL*HGT*BIN(D*PI*(TIME-START)/CYCLE+PT*PI)-
0=X (A*P(SLOPE(START)+RANDOM*NOISE)) 4-24
C AINFL=.66 4-25
C HGT=.11,CYCLE=4,PI=3.1416,PT=.5 4-26
C SLOPE=0 4-27
C RANDOM=4 4-28

N DIS(I1T06)=1/(1+PDSCNT)**J1T06 4-29
C PDSCNT=.1 4-30

```

```

PVEMP(I) PRESENT VALUE OF FUTURE MILITARY PAY EX- 4-1
PECTED BY THE AVERAGE OFFICER OF RANK I ($)
EMP(I,J) EXPECTED MILITARY PAY FOR AVERAGE OFFICER IN 4-2/11
RANK 0-4 FOR THE JTH YEAR IN THE FUTURE ($)
D(J) DISCOUNT FACTOR FOR J YEARS IN THE FUTURE 4-29
(DIMENSION D(5))
P(I) MILITARY PAY FOR RANK I ($) 4-12
FO(I) PROMOTION OPPORTUNITY TO GRADE I (PER 7-6
CENTAGE)
PDSCNT PERCEIVED DISCOUNT INTEREST RATE (DIMEN- 4-30
SIONLESS)
MPINCR(I) MILITARY PAY INCREASE RATE ($/YR) 4-15
MPI(I) INITIAL MILITARY PAY (REGULAR MILITARY 4-14
COMPENSATION) FOR RANK I ($)

```

UNCLASSIFIED

AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOO--ETC F/G 15/5
A SYSTEM DYNAMICS MODEL FOR ASSESSING THE COST-EFFECTIVENESS OF--ETC(U)
DEC 80 K L WILLIAMS
AFIT/60R/05/80D-7
NL

NL

3073
47
4014 267

END
DATE
FILMED
3-21-79
DTIC

MPINCF(I)	MILITARY PAY INCREASE FRACTION (PERCENT)	4-16
COMP	DELAYED MILITARY PAY INCREASE TO ACHIEVE "COMPARABILITY" IN RANK I (PERCENT)	4-17
RAISE(I)	MILITARY PAY INCREASE TO ACHIEVE "COMPARABILITY" IN RANK I (PERCENT)	4-18
PRONT	PERCENTAGE OF CP REQUIRED BY "COMPARABILITY" POLICY FOR RANK I (PERCENT)	4-19
AVGCP(I)	AVERAGE CIVILIAN PAY OF ALL PROFESSIONS FOR POSITIONS COMPARABLE TO RANK I (\$)	4-20
MPLAG	DELAY IN INCREASING MILITARY PAY (YRS)	4-21
OP	MILITARY PAY OP (PERCENT)	4-22
INFL	INFLATION (PERCENT)	4-24
AINFL	AVERAGE INFLATION RATE (PERCENT)	4-25
HGHT	HEIGHT OF AMPLITUDE OF SINE WAVE	4-26
CYCLE	LENGTH OF PERIOD OF SINE WAVE	4-26
PT	POINT OF INITIAL INFLATION ON SINE WAVE	4-26
SLOPE	LONG TERM INCREASE IN INFLATION (DIMENSION-)	4-27
RANDOM	COEFFICIENT OF RANDOM COMPONENT OF INFL (DIMENSIONLESS)	4-28

NOTE SECTION 5: CIVILIAN PAY

```

A PVCP,K(I1T06)=SCLPRD(ECP,K(I1T06),1,6,D,1) 5-1
A ECP,K(1,J1T02)=CP,K(1) 5-2
A ECP,K(1,J3T04)=CP,K(2) 5-3
A ECP,K(1,J5T06)=0 5-4
A ECP,K(2,J1T06)=CP,K(3) 5-5
A ECP,K(3,J1T04)=CP,K(3) 5-6
A ECP,K(3,J5T06)=P0(4)*CP,K(4)+(1-P0(4))*CP,K(3) 5-7
A ECP,K(4,J1T02)=CP,K(4) 5-8
A ECP,K(4,J4T06)=P0(5)*CP,K(5)+(1-P0(5))*CP,K(4) 5-9
A ECP,K(5,J1T03)=CP,K(5) 5-10
A ECP,K(5,J4T06)=P0(5)*CP,K(5)+(1-P0(5))*CP,K(5) 5-11
A CP,K(I1T06)=CPNDX,K*CP(I1T06) 5-12
N CP(I1T06)=CPI(I1T06) 5-13
T CPI=21428/26314/31146/37135/45195/50879 5-14
L CPNDX,K=CPNDX,JACT*RRCPR,K 5-15
N CPNDX=1 5-15
R RRCPR,KL=150+B1*CCYC,K*NDRMPN(10,0,0025))*CPNDX,K 5-17
C B0=-.01173743 5-18
C B1=.00211433 5-19
A CMD,K=120+AMPL*SIN(2*PI*(TIME-START)/CYCL+POINT*PI)+
X RAMP(CP(ATH,START)-NORMN(0,ERRSD)) 5-22
C AMPL=70,CYCL=5,POINT=.5,GROWTH=0 5-21
C ERRSD=4 5-22

```

PVFCF(I)	PRESENT VALUE OF FUTURE CIVILIAN PAY EX- PECTED BY THE AVERAGE OFFICER OF RANK I (\$)	5-1
ECP(I,J)	EXPECTED CIVILIAN PAY FOR AVERAGE OFFICER OF RANK I FOR THE JTH YEAR INTO THE FUTURE(\$)	5-2/11
CP(I)	CIVILIAN PAY FOR AN ENGINEER IN A POSITION COMPARABLE TO RANK I (\$)	5-12
CPI(I)	INITIAL CIVILIAN PAY FOR ENGINEERS IN A POSITION COMPARABLE TO RANK I (\$)	5-14
PO(I)	PROMOTION OPPORTUNITY TO GRADE I (PER CENTAGE)	7-6
D(J)	DISCOUNT FACTOR FOR J YEARS IN THE FUTURE (DIMENSIONLESS)	4-29
CPNDX	CP INDEXED WITH CPI=1 (DIMENSIONLESS)	5-15
RROPR	REAL RELATIVE RATE OF CHANGE IN CPNDX (DIMENSIONLESS)	5-17
CDMD	INDEX OF CIVILIAN DEMAND FOR ENGINEERS (DIMENSIONLESS)	5-20
AMPL	AMPLITUDE OF SINE WAVE FOR CDMD (DIMENSIONLESS)	5-21
CYCL	CYCLE LENGTH (PERIOD OF SINE WAVE) FOR CDMD (DIMENSIONLESS)	5-21
POINT	POINT OF INITIAL DEMAND ON SINE WAVE FROM $\pi - 2$ (RADIAN)	5-21
GROWTH	LONG TERM GROWTH RATE FOR CDMD (INDEX VALUE/YR)	5-21
ERRSD	STANDARD DEVIATION OF THE ERROR FOR THE NORMAL RANDOM INPUT TO CDMD (DIMENSIONLESS)	5-22

NOTE SECTION 6: ACCESSIONS

R PRML(1)=SWITCH(ACSHR0,K,ACSHR1,K,ACSNOP) 6-8
C ACSNOP=1 6-1

NOTE INITIAL ACCESSION OPTION

A ACSHR0,K=200 6-2'

NOTE ALTERNATE ACCESSION OPTION

A ACSHR1,K=MIN(GCAL,K,SUPPLY,K) 6-2
A GCAL,K=PIFGE(NEED,K,GTAL,2) 6-3
A NEED,K=MAX(SUM(AU,K)-SUM(RANK,K)+SUM(LOSS,K),0) 6-4
N NEED=1000 6-4.5
A LOSS,K(1:104)=SMOOTH(VSR,JK(1:104)+PR,JK(1:104),1) 6-6
A LOSS,K(5)=SMOOTH(VSR,JK(5)+PR,JK(5),1) 6-7
A BAL,K=BDGT,K-TOTO,K 6-8
A BDGT,K=1000+BA*F(ANBDGT,START)+PVF,K 6-9
C ANBDGT=7510 6-10
A SUPPLY,K=OFF,K+EGRAD0,K 6-11

A $PR(K) = 1.08 \times (1 + PR(K-1) - PR(K-1) \times ED + 1.05 \times ED)$ 6-14
 T $4FFT = .0027/.0029/.0037/.0044/.0051/.0059/.0068$ 6-13
 A $PPNDX(K) = SMOOTH(PAYNDX(K), ATTR)$ 6-14
 C $ATTR = 1$ 6-15
 A $EGRADS(K) = EF(K) \times TORADS(K)$ 6-16
 A $EF(K) = TABML(LEFT, POPP(K), 8, 1.2, 2)$ 6-17
 T $EFT = .24/.25/.26$ 6-18
 A $POPP(K) = SMOOTH(OPNDX(K), TIS)$ 6-19
 C $TIS = 4$ 6-20
 A $TORADS(K) = EDGROW + RAMP(EDGROW, 0)$ 6-21
 C $EDGROW = 0.007$ 6-22

PR(1)	ACCESSION RATE ("PROMOTION" TO 2LT)	6-0
	(OFFICERS/YR)	
ACONIF	ACCESSION OPTION (0 FOR PR(1)=ACONR0 OR 1 FOR PR(1)=ACON1)	6-1
GOAL	GOAL FOR ACCESSION RATE (OFFICERS/YR)	6-3
NEED	ACCESSION RATE NEEDED TO FILL VACANCIES (OFFICERS/YR)	6-4
LOSS	ESTIMATE OF NEXT YEAR'S LOSSES (OFFICERS)	6-5/7
EAL	BALANCE LEFT IN THE COST CONSTRAINT BUDGET (\$000)	6-8
EDGT	BUDGET COST CONSTRAINT (\$000)	6-9
TOTO	PRESENT VALUE OF TOTAL ACCUMULATED COSTS (\$000)	10-6
AVEDGT	ANNUAL BUDGET GROWTH RATE (\$000/YR)	6-10
SUPPLY	SUPPLY OF ENGINEERS AVAILABLE TO THE AIR FORCE (ENGINEERS)	6-11
AFF	AIR FORCE'S FRACTION OF ENGINEER GRADUATES (PERCENT)	6-12
PPNDX	PAY INDEX AS PERCEIVED BY PROSPECTIVE OFFICERS (DIMENSIONLESS)	6-1
PAYNDX	PAY INDEX (DIMENSIONLESS)	6-13
ATTR	AVERAGE TIME TO RECRUIT-DELAY FROM PAY RAISE TO ACCESSION RESPONSE (YRS)	6-15
EGRADS	ENGINEERING GRADUATES (ENGINEERS)	6-16
EF	ENGINEERING FRACTION OF TOTAL GRADUATES (ENGINEERS)	6-17
POPP	OPPORTUNITY PERCEIVED BY STUDENTS FOR AN ENGINEERING CAREER (INDEX)	6-19
TIS	TIME IN SCHOOL AVERAGE DELAY BETWEEN A STUDENT SELECTING AN ENGINEERING CURRIC- ULUM AND GRADUATION (YRS)	6-20
TORADS	TOTAL COLLEGE GRADUATES (STUDENTS)	6-21
EDGROW	GROWTH RATE FOR COLLEGE GRADUATES (STUDENTS/YR)	6-22

NOTE SECTION 7: PROPORTIONS

R PR,KL(2)=(1-VSRF,K(2))*PO(2)*OUT2,K 7-0
 A OUT2,K=SHIFTL(PIPE2,K,1) 7-1
 L PIPE2,K(1)=PIPE2,J(1)+DT*PR,JK(1) 7-2
 N PIPE2(J1T05)=PIPE2I(J1T05) 7-3
 T PIPE2I=0/315/276/265/155 7-4

R PR,KL(3)=PO(4)*OUT3,K 7-5
 T PO=1/1/1/7/7/5 7-6
 A OUT3,K=SHIFTL(PIPE3,K,1)-ALOSS3,K 7-7
 L PIPE3,K(1)=PIPE3,J(1)+DT*PR,JK(2) 7-8
 N PIPE3(J1T09)=PIPE3I(J1T09) 7-9
 T PIPE3I=0/434/127/115/99/133/115/148/210 7-10
 A ALOSS3,K=SUMV(LOSS3,K,2,9)/8 7-11
 L LOSS3,K(1)=LOSS3,J(1)+DT*LOSS3R,JK 7-12
 A LOSS3R,K=SHIFTL(LOSS3,K,1) 7-13
 N LOSS3(J1T09)=LOSS3I(J1T09) 7-14
 T LOSS3I=0/0/0/0/0/0/0/0 7-15
 R LOSS3R,KL=VSR,JK(3)-TR,JK(3) 7-16

R PR,KL(4)=PO(5)*OUT4,K 7-17
 A OUT4,K=SHIFTL(PIPE4,K,1)-ALOSS4,K 7-18
 L PIPE4,K(1)=PIPE4,J(1)+DT*PR,JK(3) 7-19
 N PIPE4(J1T06)=PIPE4I(J1T06) 7-20
 T PIPE4I=0/110/98/89/105/111 7-21
 A ALOSS4,K=SUMV(LOSS4,K,2,6)/5 7-22
 L LOSS4,K(1)=LOSS4,J(1)+DT*LOSS4R,JK 7-23
 A LOSS4R,K=SHIFTL(LOSS4,K,1) 7-24
 N LOSS4(J1T06)=LOSS4I(J1T06) 7-25
 T LOSS4I=0/0/0/0/0/0 7-26
 R LOSS4R,KL=VSR,JK(4)-VSRP04,K-TR,JK(4) 7-27
 A VSRP04,K=DELAYP((1-PO(5))*OUT4,K,ATAP4,FOYAJ5) 7-27.1
 C ATAP4=0 7-27.2

R PR,KL(5)=PO(6)*OUT5,K 7-28
 A OUT5,K=SHIFTL(PIPE5,K,1)-ALOSS5,K 7-29
 L PIPE5,K(1)=PIPE5,J(1)+DT*PR,JK(4) 7-30
 N PIPE5(J1T06)=PIPE5I(J1T06) 7-31
 T PIPE5I=0/21,62/55/51/17 7-32
 A ALOSS5,K=SUMV(LOSS5,K,2,6)/5 7-33
 L LOSS5,K(1)=LOSS5,J(1)+DT*LOSS5R,JK 7-34
 A LOSS5R,K=SHIFTL(LOSS5,K,1) 7-35
 N LOSS5(J1T06)=LOSS5I(J1T06) 7-36
 T LOSS5I=0/2/2/0/0/0 7-37
 R LOSS5R,KL=VSR,JK(5)-VSRP05,K-TR,JK(5) 7-38
 A VSRP05,K=DELAYP((1-PO(6))*OUT5,K,ATAP5,FOJLTS) 7-38
 C ATAP5=0 7-40

PR(1)	PROMOTION RATE FROM RANK 1 (FOR 1-2 TO 5)	7-8
PIPE2(J)	LTS WHO ENTERED J-1 YEARS EARLIER (OFFICERS)	7-2
PO(1)	PROMOTION OPPORTUNITY TO GRADE 1 (PER CENTAGE)	7-6
OUT3	PROMOTION RATE TO CAPT 3 YEARS EARLIER (OFFICERS/YR)	7-7
PIPE3(J)	OFFICERS PROMOTED TO CAPT J YEARS EARLIER (OFFICERS/YR)	7-8/9
ALOSS3(J)	AVERAGE OF LOSS PER YEAR GROUP OVER THE PAST 3 YEARS (OFFICERS)	7-11
PIPE31(J)	CURRENT 25XX CAPTS WITH J-1 YRS TIME IN GRADE (OFFICERS)	7-10
LOSS3(J)	CAPTS LOST J-1 YEARS EARLIER (OFFICERS)	7-12/1
DLOSS3	CAPTS LOST 3 YEARS EARLIER I.E.=LOSS3(9) (OFFICERS)	7-13
LOSS31(X)	ZERO FOR EACH J	7-15
LOSS3R	TOTAL LOSS RATE FOR CAPTS (OFFICERS/YR)	7-16
OUTX, PIPEX, ALOSSX, PIPEX1, LOSSX, DLOSSX, LOSSX1	AND LOSSXR ARE DEFINED IN AN ANALOGOUS MANNER FOR MAJ5 (X=4) AND LT COL5 (X=5)	7-17/38
POR (1)	PASSED OVER SEPARATION RATE (OFFICERS/YR)	8-0.5
VSOP4	PORTION OF VOLUNTARY SEPARATION RATE ATTRIBUTABLE TO PASSED OVER MAJ 3	7-27.1
ATAP4	AVERAGE TIME IN THE AIR FORCE AFTER PASS-OVER TO LTD (YRS)	7-27.2
POMAJ5	PASSED OVER MAJORS	
VSOP5	PORTION OF VOLUNTARY SEPARATION RATE ATTRIBUTABLE TO PASSED OVER LT COL5	7-39
ATAP5	AVERAGE TIME IN THE AIR FORCE AFTER PASS-OVER TO COL (YRS)	7-40
POLTC5	PASSED OVER LT COLONELS	

NOTE SECTION 2: SEPARATIONS DUE TO PASSOVERS

R POR.KL(1)=0 8-0
 R POR.KL(2)=0 8-1
 R POR.KL(3)=DELAYP((1-PO(4))*OUTO,PIATAP3,FOOPTS) 8-2
 C ATAP3=2 8-3
 R POR.KL(4)=0 8-4
 R POR.KL(5)=0 8-5

POR (1)	PASSED OVER SEPARATION RATE (OFFICERS/YR)	8-0/5
PO(1)	PROMOTION OPPORTUNITY TO GRADE 1 (PER CENTAGE)	7-6
OUT3	PROMOTION RATE TO CAPT 3 YEARS EARLIER (OFFICERS/YR)	7-7
ATAP3	AVERAGE TIME IN THE AIR FORCE AFTER PASS-OVER TO MAJ (YRS)	8-3
FOOPTS	PASSED OVER CAPTAINS	8-2

NOTE SECTION 9: TRANSFERS

R TR,KL(1)=0
 R TR,KL(2)=0
 R TR,KL(I2T05)=RANK,K(I2T05)*TRF,K
 A TRF,K=TABLE(TRF,TMYNO,K),.5,.2,.1)
 T TRF=.02/.01/.01/.02

TR(I)	NET TRANSFER RATE (INTO+, OUT-) FOR	9-0/1
	RANK I (OFFICERS/YR)	
RANK(I)	ASSIGNED IN RANK I (OFFICERS)	1-5
TRF	TRANSFER RATE FACTOR (PERCENT)	9-2

NOTE SECTION 10: CUMULATIVE COST CALCULATIONS
 NOTE TOTAL COSTS

A TOTC,K=TSERP,K+ACCC,K+PSC,K+TANNO,K+VRETC,K 10-0
 NOTE PRESENT VALUE FACTOR

A PVF,K=1/(1+DISCNT)**(TIME-START) 10-1
 C DISCNT=.1 10-2

NOTE ANNUAL PERSONNEL COSTS

A TANNO,K=SUM(ANNO,K) 10-3
 L ANNO,K(1)=ANNO,U(1)+DT*ANNOR,JK(1) 10-4
 N ANNO(1)=0 10-5
 R ANNOR,KL(1)=0 10-6
 L ANNO,K(I2T05)=ANNO,U(I2T05)+DT*ANNOR,JK(I2T05) 10-7
 N ANNO(I2T05)=ANNO,I(I2T05-1) 10-8
 T ANNOR=0/0/2/0/0 10-9
 R ANNOR,KL(I2T05)=RANK,K(I2T05)*ANNOR(I2T05)*PVF,K 10-10
 A ANNOR,K(1)=0 10-11
 A ANNOR,K(2)=AFCF(2)*(MF,K(1)+MP,K(2))/2000 10-12
 A ANNOR,K(I2T05)=AFCF(I2T05)*MP,K(I2T05)/1000 10-13
 T ACF=0/.92/.99/.98/.97 10-14

NOTE VOLUNTARY SEPARATION COSTS

A TSEPC,K=SU*(SEPC,K) 10-15
 L SEPC,K(I1T05)=SEPC,J(I1T05)+DT*VSR,JK(I1T05)*
 Y SEPCF,J(I1T05)*PVF,J 10-18
 N SEPC(I1T05)=SEPC(I1T05) 10-19
 T SEPC=0/0/0,0/0 10-20
 A SEPCF,K(I1)=0 10-21
 A SEPCF,K(I2T05)=FSCC+RETC,K(I2T05) 10-22
 C FSCC=4 10-23
 A RETC,K(I1T05)=FRET(I1T05)+APRONT(I1T05)*BASEF(I1T05)*
 X MP,K(I1T05)*PVF(I1T05)/1800 10-25
 T FRET=0/0/0,0/0 10-26
 N APRONT(I1T05)=.5*(AYRSDV(I1T05)-20)+.025 10-27
 T AYRSDV=0-2/20/27/24 10-28
 N BASEF(I1T05)=0+SEPC(I1T05)/VFI(I1T05) 10-29
 T BASEFI=12995/1-56/1/1996/22930/27820 10-30
 A PVFI(I1T05)=(1-1/(1+DISCNT))*N(I1T05)/(1-1/(1-DISCNT)) 10-31
 N N(I1T05)=LIFEXP-(21+AYRSDV(I1T05)) 10-32
 C LIFEXP=70 10-33

NOTE ACCESSION COSTS

L ACCC,K=ACCC,J+DT*ACCCF*FR,JK(I1)*PVF,J 10-34
 N ACCC=0 10-35
 C ACCCF=27 10-36

NOTE VESTED RETIREMENT COSTS

L VRETC,K=VRETC,J+DT*FR,JK(5)*SEPCF,J(5)*PVF,J 10-37
 N VRETC=0 10-38

NOTE FORCED SEPARATION COSTS

L FSC,K=FSC,J+DT*(FCR,JK(5))*FSCF*PVF,J 10-39
 N FSC=0 10-40
 N FSCF=FSCC+SEVPAY 10-41
 C SEVPAY=15 10-42

TOTC	PRESENT VALUE OF TOTAL ACCUMULATED COSTS (\$000)	10-0
PVF	PRESENT VALUE FACTOR (DIMENSIONLESS)	10-1
DISCNT	DISCOUNT INTEREST RATE (PERCENT)	10-2
TANVC	TOTAL ANNUAL PERSONNEL COSTS (\$000)	10-3
ANNO(I)	TOTAL ANNUAL COSTS FOR RANK I (\$000)	10-7
ANNOF(I)	ANNUAL COST RATE FOR RANK I (\$000/YR)	10-10
RANK(I)	ASSIGNED IN RANK I (OFFICERS)	1-5
ANNOF(I)	ANNUAL COST FACTOR FOR RANK I	10-1
AFRCF(I)	AIR FORCE COST FRACTION FOR OFFICERS OF RANK I (PERCENT)	
MP(I)	MILITARY PAY FOR RANK I (\$)	4-12
TSEPC	TOTAL ACCUMULATED VOLUNTARY SEPARATION COSTS (\$000)	10-15
SEPC(I)	ACCUMULATED VOLUNTARY SEPARATION COSTS FOR RANK I (\$000)	10-18
SEPCF(I)	VOLUNTARY SEPARATION COST FACTOR FOR RANK I (\$000/OFFICER)	10-22
POSC	PERMANENT CHANGE OF STATION COSTS (\$000)	10-23
RETC	RETIREMENT COSTS (\$000)	10-24
PRET	PERCENTAGE OF RETIREMENTS FROM RANK I (PERCENT)	10-26
APRCNT	AVERAGE PERCENT OF BASE PAY AUTHORIZED RETIREES FROM RANK I (PERCENT)	10-27
AYRSC(I)	AVERAGE YEARS SERVICE OF RETIREES FROM RANK I (YEARS)	10-28
BASEF(I)	BASE PAY AS A FRACTION OF MILITARY PAY (REGULAR MILITARY COMPENSATION) FOR RANK I (PERCENT)	10-29
BASEF(I)	INITIAL BASE PAY FOR RANK I (\$)	10-30
MP(I)	INITIAL MILITARY PAY (REGULAR MILITARY COMPENSATION) FOR RANK I (\$)	4-14
RPVF(I)	PRESENT VALUE FACTOR FOR FUTURE PAY FOR RETIREES FROM RANK I (DIMENSIONLESS)	10-31
N(I)	AVERAGE YEARS RETIREES FROM RANK I ARE PAID (YEARS)	10-32
LIFEXP	LIFE EXPECTANCY (YEARS)	10-33
ADCC	ACCUMULATED ACCESSION COSTS (\$000)	10-34
ADCCF	ACCESSION COST FACTOR (\$000/OFFICER)	10-36
PR(I)	ACCESSION RATE (PROMOTION TO 2LT) (OFFICERS/YR)	6-2
VRETC	ACCUMULATED VESTED RETIREMENT COSTS FOR LT COLS PROMOTED TO COL (\$000)	10-37
PR(I)	PROMOTION RATE FROM RANK I (FOR 1-2 TO 5)	7-3
FSC	ACCUMULATED FORCED SEPARATION COSTS (\$000)	10-39
FSCF	FORCED SEPARATION COST FACTOR (\$000/OFFICER)	10-41
SEVPAY	SEVERANCE PAY (\$000/OFFICER)	10-42
FOR (I)	FORCED OVER SEPARATION RATE (OFFICERS/YR)	6-6/5

Appendix C
Demographic Data for Development Engineer Officer
Responses to the Air Force Quality of Life Survey

TABLE C-I
GRADE DISTRIBUTION OF 28XX RESPONDENTS

Grade	Number	Percent of Total	Total AF* Assigned	Percent of Total
2nd Lt	18	22	1011	27%
1st Lt	9	11		
Capt	15	18	1405	37
Maj	14	18	799	21
Lt Col	16	20	498	13
Col	<u>8</u>	10	<u>102</u>	3
Total	80		3815	

*As of August 1980 (AFMPC, 1980b)

TABLE C-II
DISTRIBUTION BY COMMAND OF 28XX RESPONDENTS

Command	Number	Percent of Total
Systems Command	52	65
Logistics Command	5	6
Air Training Command	4	5
HQ USAF	4	5
Strategic Air Command	3	4
Electronic Security Command	3	4
Air Force Academy	2	2
Other	<u>7</u>	9
Total	80	

Appendix D
Productive Capacity Function

Purpose of This Appendix

This annex describes the efforts to develop a function for comparing the productive capacity of development engineer officer forces composed of different numbers of officers in each grade. This function is to provide an ordinal measure of effectiveness distinguishing between the outcomes of alternative retention policies. The particular alternatives considered in this thesis deal with tradeoffs between accession incentives which offer a greater potential for increasing total development engineer manpower (Gaffney, 1980:10) and retention incentives which would increase the number of experienced engineers. Thus the productive capacity function must provide an indicator of the effectiveness of a development engineer officer force, with many inexperienced officers relative to a smaller more experienced force.

The objective of this part of the thesis is intentionally limited. From the outset, the goals were to develop an approximate measure of effectiveness and, in so doing, determine a feasible technique for measuring the relationship between experience levels, force size and productive capacity. The approximate measure provided a

basis for sensitivity analysis to determine if a more extensive investigation would be warranted.

Overview

Since a more thorough investigation may prove to be useful, this annex describes the approaches which did not produce results as well as those which did. The discussion will begin by defining the attributes which characterize alternative development engineer officer forces and productive capacity which is assumed to be a function of these attributes. Then, the next section gives some examples of production functions used in previous military personnel studies which serve as an indicator of potential forms of the productive capacity function. Following that, the investigations to determine an appropriate form of the function are described. After a hypothesized form of the function is developed, the elicitation process used to estimate the function's parameter values is described. The final sections discuss possible interpretations of the results and the test conducted to validate the model of productive capacity.

Definition of Attributes and the Productive Capacity Function

The attributes of a development engineer officer force which would be influenced dramatically by a change in retention policies are the numbers of officers in the various grades or experience levels. To simplify the

estimation process, alternative development engineer forces were assumed to be adequately described for comparison purposes by the numbers of Lieutenants (Second Lieutenants and First Lieutenants), Captains, and Field Grade Officers (Majors plus Lieutenant Colonels). This assumes that the contributions to organizational effectiveness made by Second Lieutenants versus First Lieutenants or Majors versus Lieutenant Colonels are not sufficiently different to warrant disaggregation. This implication is not viewed as a strong weakness since most policies which influence the number of Second Lieutenants or Majors would, over time, effect the number of First Lieutenants or Lieutenant Colonels in approximately the same proportion.

Grade level groups were selected as the attributes as a convenience in the elicitation process. This assumes that commanders find it easier to think in terms of the capabilities typically provided by officers of different grades than the capabilities associated with years of experience. Another advantage of grade level attributes is that they can be readily compared to the approved authorization structure.

It is important to note that the grade level is used as a surrogate for experience; the elicitation process assumed no dramatic change from current promotion timing nor opportunity. If promotion policies are assumed to vary, the effect on the productive contribution of the various grades must be accounted for. For example, if the

opportunity for promotion to Major is increased, it would be reasonable to hypothesize that the average productivity of Majors would decrease.

Given the attributes selected, the research described in this annex is devoted to estimating the function

$$P(L,C,F)$$

where P is the productive capacity of a development engineer officer force composed of L Lieutenants, C Captains, and F Field Grade Officers.

A few words indicating what is meant by "productive capacity" are probably in order. For an organization with a quantifiable output, the productive capacity would be the total production associated with a particular labor force assuming fixed amounts of capital and other supporting resources. In a widget factory, production would be the quantity of widgets produced multiplied by an indicator of the quality, say the price per widget. Any form of the productive capacity function could be estimated via regression techniques given a sufficient number of observations of production with the associated number of laborers in each category of interest.

Unfortunately, there is no readily identifiable quantitative measure of the output of an Air Force engineering organization nor is there a particular measure of the quality of such output. Consequently, the "production" associated with a given development engineer officer force

must be estimated by some subjective elicitation technique. This process is then, in effect, an elicitation of Air Force commanders' preference structures, or value functions, for various force combinations. This assumes that the value of personnel in an establishment is a matter of what they can do rather than who they are (Fisher, 1969:90).

To develop the first approximation of $P(L,C,F)$, arrangements were made to interview an experienced manager in an Air Force engineering organization. This decision maker was Deputy Director of the Flight Systems Engineering Directorate of the Aeronautical Systems Division of the Air Force Systems Command. The results of these interviews are applicable to the Air Force as a whole to the extent that this particular organization is typical of all establishments employing Air Force development engineering officers. Since only a rough approximation of the Air Force-wide function is sought, the responses obtained from this single decision maker who has been intimately involved in development engineering should be sufficient.

Form of the Productive
Capacity Function

Additive Form. One of the initial objectives of the interviews was to determine the form of P , the productive capacity function. The simplest P function is the additive form

$$P(L,C,F) = \beta_1 P_1(L) + \beta_2 P_2(C) + \beta_3 P_3(F)$$

where β_1 , β_2 , and β_3 are constants and P_1 , P_2 , and P_3 are functions of only their respective arguments.

This particular form may seem implausible at extreme values. For example, if $\beta_3 > \beta_2 > \beta_1$, then the most productive organization of a given size may be composed entirely of Field Grade Officers. However, additive forms of production functions have been used in similar military manpower studies so there is cause to expect that, within a reasonable range of the values of L , C , and F , this form may be adequate.

Several cost-effectiveness studies of military manpower have been performed by RAND corporation using their static manpower optimization model (Jaquette, 1978:71-75) which includes a linear production function of the form

$$P = \sum_{i=1}^5 s_i x_i$$

where x_i = the number of personnel in the one of five years in service periods of four years each and s_i = a constant productivity weight.

In a study of optimal reenlistment policies for Navy electronic technicians, Fisher and Morton (1967:379:380) used a Cobb-Douglas production function such as

$$P = \prod_{i=1}^5 x_i^{\beta_i}$$

where the x_i 's represent numbers in various years of service groups and the β_i 's are constants.

This Cobb-Douglas function can be changed into an additive form by the logarithm transformation:

$$\text{Let } P' = \ln P$$

$$\text{and } X' = \ln x_i$$

$$\text{Then } P' = \sum_{i=1}^5 \beta_i x_i'$$

Since P is assumed to be ordinal, any monotonic transformation of itself preserves the preference structure (Fisher, 1969:86). So the Cobb-Douglas formation is also of the additive form.

Multi-attribute utility theory indicates that a necessary and sufficient condition for a value function to have the additive form is that the attributes be mutually preferentially independent (Keeney and Raiffa, 1976:111). In layman's language, mutual preference independence means that the tradeoff between any two attributes does not depend upon the value of any other attribute. The validity of this assumption was tested in one of the initial interviews with the decision maker.

At the beginning of the initial elicitation interview, the decision maker was asked to consider himself the commander of the "average" organization depicted in Table D-I. This average organization structure was developed by prorating the total number of 28XX authorizations in the decision maker's actual organization into grade levels in the same proportion as the total of the

TABLE D-I
HYPOTHETICAL ORGANIZATION FOR CHECKING
INDEPENDENCE CONDITIONS

Grade	USAF 28XX Authorizations	"Average" USAF Organization	Range of Officers Assigned
Lt	533	10	5-25
Capt	2362	44	25-60
Maj	935	17	28 15-40
Lt Col	<u>563</u>	<u>11</u>	
Total	4393	82	45-125

Air Force's 28XX authorizations (AFMPC, 1980). This was done so that the results could be easily applied to the Air Force-wide 28XX manning.¹ Since the decision maker was experienced in making decisions related to his own organization's manning, this sizing down of the Air Force authorization structure was expected to make the elicitation process easier for him. These tradeoffs could be viewed as exchanges with another commander trading "typical" officers while considering only the benefit to the decision maker's organization. Having introduced the technique, the decision maker was asked to state his preference between point B and point C of Figure D-1. That is to say, given that his organization had 5 Lieutenants of the 10 authorized, would he prefer to have 40 Field Grade Officers compared

¹This assumes that 28XX officers are distributed evenly among all organizations and that this decision maker's preferences and organization are representative of the Air Force 28XX community as a whole.

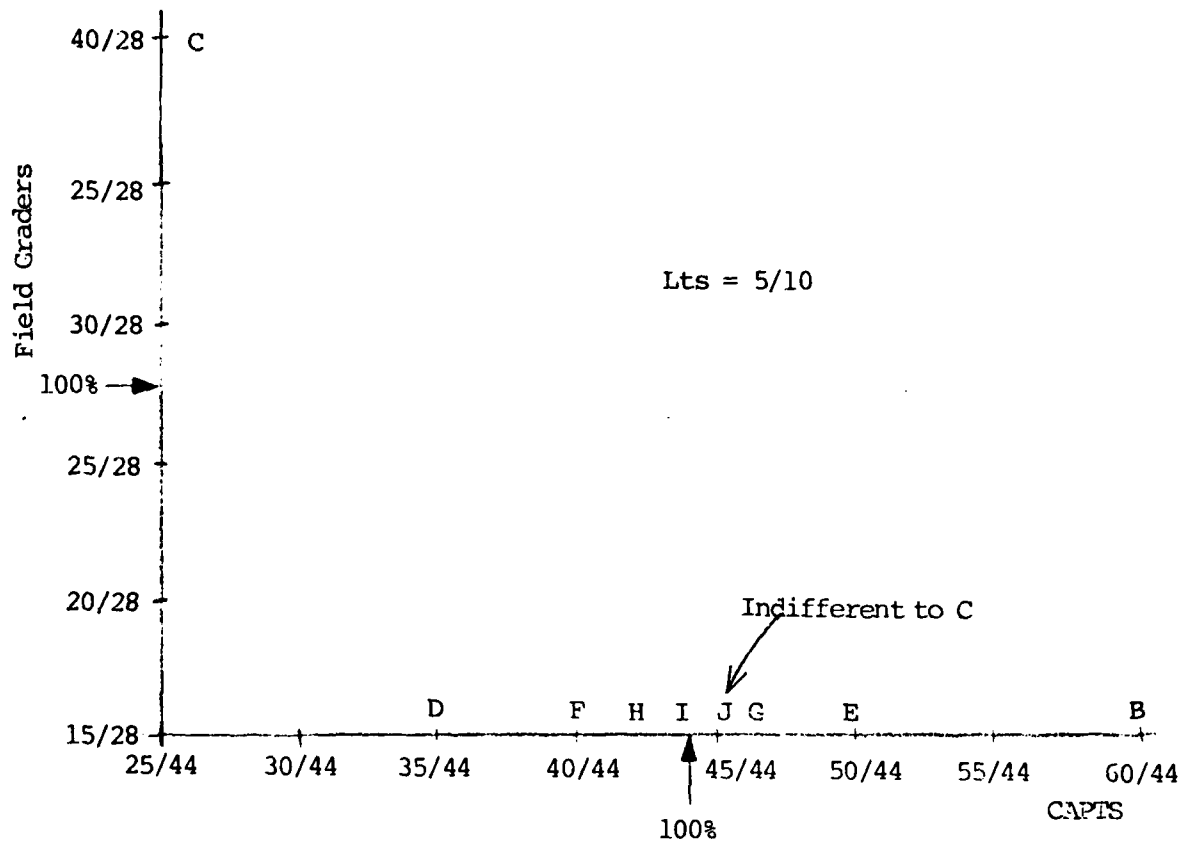


Fig. D-1. Field Grade Officer vs. Captain Tradeoffs
With Low Lieutenant Manning

with 28 authorized and 25 of 44 authorized Captains or 15 Field Grades and 60 Captains. After he indicated that point B was preferred to C, different points along the Captain scale were tried to iteratively arrive at point J which was indifferent to point C. This entire procedure was repeated as shown in Figure D-2 with the exception that the decision maker was to assume that his organization had 25 Lieutenants compared to 10 authorized. In this second case G was the point indifferent to C. Since the indifference point of Figure D-1 was different than the one in Figure D-2 depending upon the value of the other attribute (the number of Lieutenants), mutual preference independence of the attributes could be ruled out. Consequently, the simple additive form of P was eliminated.

Multiplicative Form. Another common form of many value functions is the multiplicative form

$$P(L,C,F) = (1+KK_1P_1(L))(1+KK_2P_2(C))(1+KK_3P_3(F))$$

This form, like the additive form, allows the analyst to separately elicit the individual P_i function for each attribute and only requires the estimation of one additional parameter value. A necessary and sufficient condition for a value function to have this multiplicative form is that the attributes be mutual weak difference independent (Dewispelaire and Sage, 1979:442). In this case, mutual weak difference independence means that if the

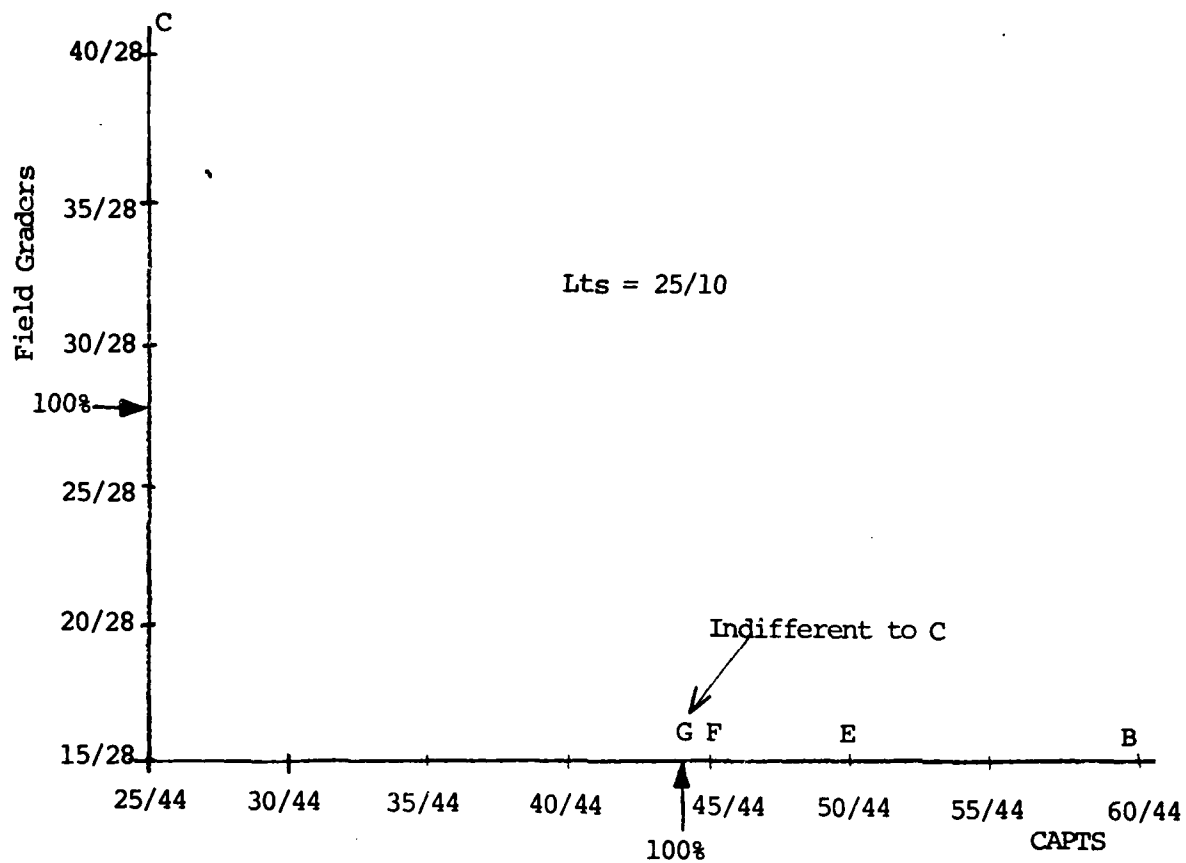


Fig. D-2. Field Grade Officers vs. Captain Tradeoffs
With High Lieutenant Manning

exchange between two levels of officers in a particular grade is preferred to the exchange between two other levels of that grade, then the first exchange must be preferred regardless of the numbers of officers in the other grades. This assumption was refuted by presenting the decision maker with the exchanges depicted in Figure D-3. In response to the first question, the decision maker selected the exchange from A to B over the exchange from B to C. This indicated that the increase in productive capacity going from 40 Captains up to 44 Captains (the authorized strength) was greater than the increase in going from 44 Captains up to 50. In the second situation, however, he preferred the exchange from 44 up to 50 Captains because he felt a greater need for Captains when the other grades were well below their authorized levels. Therefore, the attributes defined for this exercise were not weak difference independent to the decision maker. Consequently, the multiplicative form of P was ruled out as well.

Ad Hoc Model. Since it appeared that P could not be adequately represented by a relatively simple multi-attribute utility theory preference elicitation, an ad hoc simulation technique was also investigated. The decision maker was asked to estimate the effectiveness of the "typical officer" in positions calling for the rank both one below and one higher than his own grade. This measure was to indicate the officer's effectiveness in the job

Of the following exchanges which would increase productive capacity more, going from A to B or from B to C?

	<u>A^a</u>				<u>B</u>				<u>C</u>		
	LTS	CAPTS	FGS		LTS	CAPTS	FGS		LTS	CAPTS	FGS
1.	(10/10	40/44	28/28)	→	(10/10	44/44	28/28)	→	(10/10	50/44	28/28)

Now which is the greater increase from A' to B' or B' to C'?

	<u>A'</u>				<u>B'</u>				<u>C'</u>		
	LTS	CAPTS	FGS		LTS	CAPTS	FGS		LTS	CAPTS	FGS
2.	(5/10)	40/44	15/28)	→	(5/10	44/44	15/28)	→	(5/10	50/44	15/28)

^aThe points are represented as ratios of the assigned to authorized number of Lieutenants, Captains, and Field Grade Officers respectively.

Fig. D-3. Check for Weak Difference Independence

relative to an officer of the authorized rank. The decision maker's responses are shown in Table D-II.

TABLE D-II
SUBJECTIVE PARAMETER ESTIMATES FOR AN AD HOC
PRODUCTIVE CAPACITY MODEL

The effectiveness of a _____	in a _____ billet relative to a _____	is
Lt Col	Maj	1.2
Maj	Lt Col	.8
Maj	Capt	.75
Capt	Maj	.7
Capt	Lt	2.0
Lt	Capt	.6

These parameter estimates were used in a model which calculates an effectiveness measure for each grade, based on the assumption that all higher ranking vacancies will be filled with officers of the next lower rank and officers in excess of the authorizations available in their grade or higher grades are forced down into a position of the next lower rank. These effectiveness measures for each grade were then weighted by the authorizations in that grade to formulate a hypothetical overall effectiveness measure. An example of such a calculation, using a tableau to determine the assignments and the simplified form of P, is shown in Figure D-4.

		BILLETS				
BODIES		LTS	CAPTS	MAJS	LT COLS	TOTAL
	LTS	1	.6			5
	CAPTS	2.0	1	.7		20
	MAJS		.75	1	.8	24
	LT COLS			1.2	1	16
	TOTAL	10	44	17	11	82 70

$$P(5,20,24,16) = [(5)(.6) + (20)(1) + (12)(.75) + (12)(1) + 5(1.2) + (11)(1)] / 82 = .80$$

Fig. D-4. Sample of Ad Hoc Productive Capacity Calculations

This method was tested by using force combinations for which the decision maker had already stated his preferences. Unfortunately, the model proved to be no better than a coin toss in selecting the decision maker's preferred alternative of several different pairings. That is to say, for pairs of force combinations, the decision maker's preferred combination had a higher effectiveness measure only 50 percent of the time. Therefore, this ad hoc approach was dropped. Although this effort was clearly unsuccessful, the elicitation process was relatively straightforward; the decision maker appeared to have little difficulty in providing the subjective estimates. This would be a distinct advantage if the model could be refined to yield meaningful results.

Second Order Polynomial Form. The investigations to this point had indicated that the productive capacity of development engineer officers is not a simple separable function of the number of Lieutenants, Captains, and Field Grade Officers. Efforts to develop an alternative attribute set which would be independent also proved fruitless. In the interviews, the decision maker had indicated that production was related to total manning by a curve similar to that shown in Figure D-5. It was therefore hypothesized that P could be approximated by a second order polynomial of the form

$$P(L,C,F) = \sum_{i,j,k} \alpha_{ijk} L^i C^j F^k \quad i,j,k = 0,1, \text{ or } 2.$$

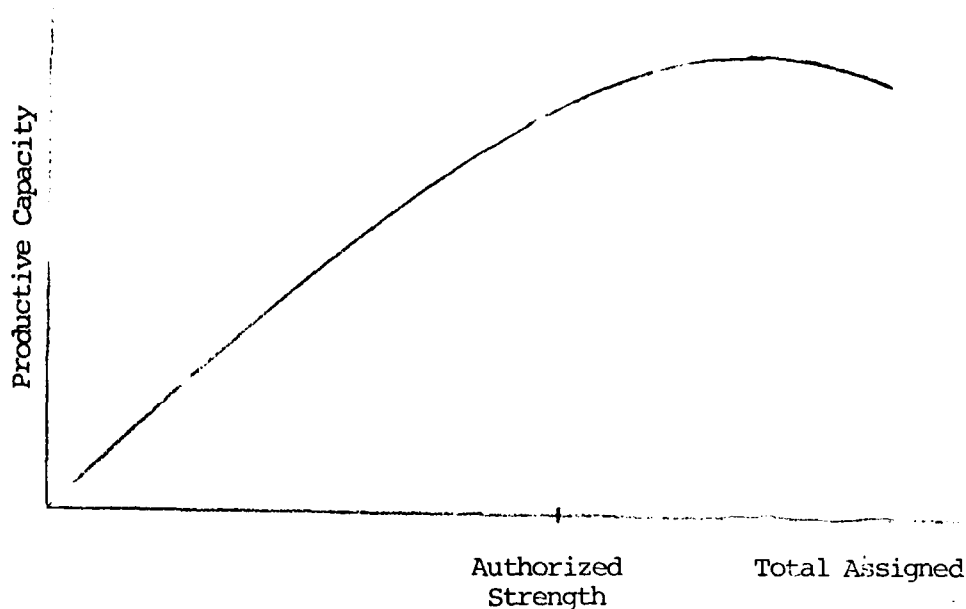


Fig. D-5. General Relationship Between Assigned 28XX Officers and Production

The remainder of the investigation was devoted to estimating appropriate parameters for a productive capacity function of this form.

Parameter Estimation

To estimate the values of the α_{ijk} parameters, the decision maker was asked to score each of 60 different force combinations on a scale of 0 to 100. A score of 100 was defined as the productive capacity when manning is exactly equal to the authorized strength in each grade; a score of 0 was associated with zero manning. In this sense, P can be thought of as the percentage of the capacity required to complete the full mission reflected by the authorized strength.

To facilitate the comparison of Air Force-wide manning of difference force combinations, the "average" Air Force engineering organization was increased to 100 28XX officers as shown in Table D-III. The feasible range for each grade was established by reviewing the extreme values in Air Force manning reports (AFMPC, 1976-1980) over the last five years. The manning levels for observations were selected with emphasis on levels close to the authorized strength to improve the accuracy of the function in that region. All combinations exceeding a total of 100, or less than 70, officers were eliminated since they were viewed as being outside the relevant range for total manning. The force combinations are presented along with the decision maker's responses in Table D-IV. Although the combinations were sorted in descending order with respect to total manning, the order within a given total was random.

TABLE D-III

HYPOTHETICAL ORGANIZATION FOR SECOND ORDER
POLYNOMIAL ELICITATION

Grade	USAF 28XX Authorizations	"Average" USAF Organization	Range of Officers Assigned
Lt	533	12	8 (67%) - 30 (250%)
Capt	2362	54	30 (56%) - 55 (102%)
Maj	935	21	34 20 (59%) - 35 (103%)
Lt Col	<u>563</u>	<u>13</u>	
Total	4393	100	70 (70%) - 100 (100%)

TABLE D-IV

SUBJECTIVE ESTIMATES OF PRODUCTIVE CAPACITY ASSOCIATED WITH VARIOUS MANNING LEVELS

PERCENT OF AUTHORIZATIONS				NUMBER OF 28XX OFFICERS ASSIGNED				PERCENT OF TOTAL ASSIGNED			Estimated Productive Capacity
LTS	CPTS	FGS	TOTAL	LTS	CPTS	FGS	TOTAL	LTS	CPTS	FGS	
100%	100%	100%	100%	12	54	34	100	12%	54%	34%	100 ^a
250%	74%	88%	100%	30	40	30	100	30%	40%	30%	89.7
83%	102%	103%	100%	10	55	35	100	10%	55%	35%	101.4
167%	93%	88%	100%	20	50	30	100	20%	50%	30%	94.0
117%	98%	97%	100%	14	53	33	100	14%	53%	33%	98.4
250%	93%	59%	100%	30	50	20	100	30%	50%	20%	60.0
117%	102%	88%	99%	14	55	30	99	14%	56%	30%	95.7
117%	93%	103%	99%	14	50	35	99	14%	51%	35%	98.8
83%	98%	103%	98%	10	53	35	98	10%	54%	36%	99.7
83%	102%	97%	98%	10	55	33	98	10%	56%	34%	98.5
117%	98%	88%	97%	14	53	30	97	14%	55%	31%	94.1
117%	93%	97%	97%	14	50	33	97	14%	52%	34%	95.9
83%	98%	97%	96%	10	53	33	96	10%	55%	34%	96.8
250%	56%	103%	95%	30	30	35	95	32%	32%	37%	88.6
83%	102%	88%	95%	10	55	30	95	11%	58%	32%	94.1

^aCombinations which have the same proportion in each grade as the authorized structure.

TABLE D-IV--Continued

PERCENT OF AUTHORIZATIONS				NUMBER OF 28XX OFFICERS ASSIGNED				PERCENT OF TOTAL ASSIGNED			Estimated Productive Capacity
LTS	CPTS	FGS	TOTAL	LTS	CPTS	FGS	TOTAL	LTS	CPTS	FGS	
167%	74%	103%	95%	20	40	35	95	21%	42%	37%	92.9
83%	93%	103%	95%	10	50	35	95	11%	53%	37%	97.2
167%	102%	59%	95%	20	55	20	95	21%	58%	21%	55.0
92%	94%	94%	94%	11	51	32	94	12%	54%	34%	94.1 ^a
117%	93%	88%	94%	14	50	30	94	15%	53%	32%	91.5
167%	98%	59%	93%	20	53	20	93	22%	57%	22%	53.0
83%	93%	97%	93%	10	50	33	93	11%	54%	35%	94.3
167%	74%	97%	93%	20	40	33	93	22%	43%	35%	90.0
83%	98%	88%	93%	10	53	30	93	11%	57%	32%	92.4
250%	56%	97%	93%	30	30	33	93	32%	32%	35%	85.0
92%	91%	91%	91%	11	49	31	91	12%	54%	34%	90.9 ^a
250%	56%	88%	90%	30	30	30	90	33%	33%	33%	81.3
83%	93%	88%	90%	10	50	30	90	11%	56%	33%	89.9
167%	93%	59%	90%	20	50	20	90	22%	56%	22%	52.0
167%	74%	88%	90%	20	40	30	90	22%	44%	33%	85.6
250%	74%	59%	90%	30	40	20	90	33%	44%	22%	50.0
117%	74%	103%	89%	14	40	35	89	16%	45%	39%	90.4
117%	102%	59%	89%	14	55	20	89	16%	62%	22%	48.0

TABLE D-IV--Continued

PERCENT OF AUTHORIZATIONS				NUMBER OF 28XX OFFICERS ASSIGNED				PERCENT OF TOTAL ASSIGNED			Estimated Productive Capacity
LTS	CPTS	FGS	TOTAL	LTS	CPTS	FGS	TOTAL	LTS	CPTS	FGS	
117%	98%	59%	87%	14	53	20	87	16%	61%	23%	46.0
117%	74%	97%	87%	14	40	33	87	16%	46%	38%	87.5
83%	74%	103%	85%	10	40	35	85	12%	47%	41%	88.8
167%	56%	103%	85%	20	30	35	85	24%	35%	41%	84.5
83%	85%	85%	85%	10	46	29	85	12%	54%	34%	85.1 ^a
83%	102%	59%	85%	10	55	20	85	12%	65%	24%	46.0
117%	74%	88%	84%	14	40	30	84	17%	48%	36%	83.1
117%	93%	59%	84%	14	50	20	84	17%	60%	24%	45.0
83%	74%	97%	83%	10	40	33	83	12%	48%	30%	85.9
83%	98%	59%	83%	10	53	20	83	12%	64%	24%	45.0
167%	56%	97%	83%	20	30	33	83	24%	36%	40%	81.6
250%	56%	59%	80%	30	30	20	80	38%	38%	25%	42.0
83%	74%	88%	80%	10	40	30	80	13%	50%	38%	81.5
167%	56%	88%	80%	20	30	30	80	25%	38%	38%	77.2
167%	74%	59%	80%	20	40	20	80	25%	50%	25%	46.0
83%	93%	59%	80%	10	50	20	80	13%	63%	25%	50.0
83%	80%	79%	80%	10	43	27	80	12%	54%	34%	79.6 ^a
117%	56%	103%	79%	14	30	35	79	18%	38%	44%	82.0

TABLE D-IV--Continued

PERCENT OF AUTHORIZATIONS				NUMBER OF 28XX OFFICERS ASSIGNED				PERCENT OF TOTAL ASSIGNED			Estimated Productive Capacity
LTS	CPTS	FGS	TOTAL	LTS	CPTS	FGS	TOTAL	LTS	CPTS	FGS	
117%	56%	97%	77%	14	30	33	77	18%	39%	43%	79.1
75%	76%	76%	76%	9	41	26	76	12%	54%	34%	76.1 ^a
83%	56%	103%	75%	10	30	35	75	13%	40%	47%	80.4
117%	74%	59%	74%	14	40	20	74	19%	54%	27%	45.0
117%	56%	88%	74%	14	30	30	74	19%	41%	41%	83.1
83%	56%	97%	73%	10	30	33	73	14%	41%	45%	77.5
67%	70%	71%	70%	8	38	24	70	12%	54%	34%	70.2 ^a
83%	56%	88%	70%	10	30	30	70	14%	43%	43%	73.1
167%	56%	59%	70%	20	30	20	70	29%	43%	29%	40.0
83%	74%	59%	70%	10	40	20	70	14%	57%	29%	44.0

This direct elicitation procedure proved to be rather difficult but the decision maker quickly devised a simplifying model to assist in scoring all combinations except those which had the extreme low value for field grade officers (20 out of 34 authorized). These remaining alternatives were scored directly by the decision maker. The decision maker's argument in support of the simplifying model is depicted in Figure D-6. He estimated that the average Captain contributes twice as much to production as the average Lieutenant and the average Field Grade Officer contributes 75 percent more than the average Captain.² He indicated that this was only true when there are (1) proper amounts of experienced supervisors so that individual efforts are well coordinated and (2) a sufficient number of subordinates so that higher ranking officers are not required to perform tasks beneath their capabilities. So within these constraints

$$P(L,C,F) = \alpha L + 2\alpha C + 3.5\alpha F$$

By definition

$$P(12,54,34) \equiv 100$$

so that

$$\alpha \approx .42$$

and therefore

$$P(L,C,F) = .42L + .84C + 1.46F$$

²In addition to this subjective judgement, Koser (1976) demonstrated with objective data that there is a statistically significant positive correlation between grade level and the productivity of scientists and engineers.

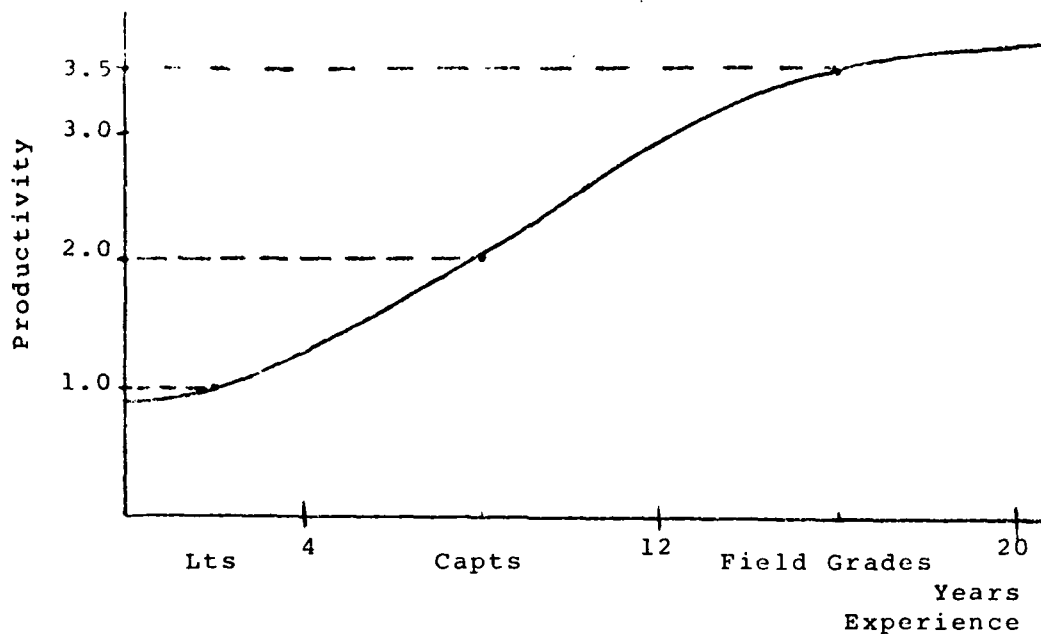


Fig. D-6. Decision Maker's View of Increase of Average Productivity with Experience

However, as the earlier investigations indicated, these constraints are too restrictive to apply to a reasonable range of the attributes.

To estimate P throughout the relevant range, the combinations and scores were input to an ordinary least squares regression using the Statistical Package for the Social Sciences (Nie, et al., 1975:320-367). The stepwise method was used since (1) the expectation (and hope) was that most of the α_{ijk} values would not be significantly different from zero and (2) the research so far had not revealed a specific model form. The regression results are presented in Table D-V. The model fit appears to be quite reasonable with one question. The Durbin-Watson

TABLE D-V

SUMMARY OF REGRESSION RESULTS

Step	Variable Entered	F to Enter	Significance	R Square	Overall F	Significance
1	F	319.1	<.01	.8440	319.1	<.01
2	CF	68.7	<.01	.9286	376.9	<.01
3	F ²	109.6	<.01	.9756	758.6	<.01
4	L ² C ²	62.8	<.01	.9885	1201.2	<.01
5	C ²	6.3	.015	.9897	1053.6	<.01

Highest F value of variables not in the equation after Step 5 = .97 (significance = .33) for L²F².

Final Model:

$$P(L,C,F) = 12.91364F + .031018865CF - .20186569F^2 \\ + .0000061566605L^2C^2 - 153.51029$$

Mean Square Error = 4.2

Variable	95% Confidence Interval of Coefficient
F	(11.39,14.44)
CF	(.022,.040)
F ²	(-.23,-.18)
L ² C ²	(.0000047,.0000076)
C ²	(-.0074,-.00083)
Constant	(-174.1,-132.9)

Durbin-Watson Test = 1.14 < 1.25 (lower bound of Durbin-Watson statistic for six parameter estimates within 60 observations).

statistic implies that the residuals are positively autocorrelated but this is likely due to the method of selecting combinations for scoring, in particular the grouping of more observations closer to the authorized levels. At any rate, given the overall imprecision of the elicitation process, this indication of heteroschedasticity is of relatively little concern.

Another noteworthy aspect of the numerical results is that after step 4, three variables had an F value greater than 4.0: $C(F=5.37)$, $C^2(F=6.33)$, and $L^2C^2(F=5.04)$. After C^2 was included, the other F values dropped to insignificance. The point to be made from this is that minor variations in the scores input to the regression, could be expected to yield not only different parameter estimates but a different model as well.

Interpretation

It is important to realize that in spite of the encouraging numerical results, the basis for the regression was very subjective. Wariness is particularly appropriate given the heroic assumption that the responses of the decision maker interviewed are typical of all commanders of Air Force engineering organizations. Another weakness in the model is the paucity of meaningful interpretations. That is to say, there is no obvious a priori argument in favor of the form

$$P(L,C,F) = \beta_1 F + \beta_2 CF - \beta_3 F^2 + \beta_4 L^2 C^2 - \beta_5 C^2 - \beta_6$$

$$\beta_i > 0 \quad \forall_i = 1, 2, \dots, 6$$

over many other possible forms.

However, the model does contain several features which appear to be realistic approximations of the real world. For example, as shown in Figures D-7, D-8, and D-9, whenever two of the attributes are held fixed, increasing the value of the remaining attributes provides additional productive capacity. In other words, within the relevant range, more is preferred to less. However, the negative coefficients of the F^2 and C^2 terms imply that there is a diminishing return for increases in Field Grade Officers and Captains. The CF term implies that Field Grade Officers are more productive when there are more Captains present and vice versa. This seems reasonable since when Captains are in short supply, Field Grade Officers are forced to perform work which contributes less to production than officers with their experience are capable of. On the other hand, in the absence of more experienced supervision, Captains' efforts may become less well coordinated and thus make less of a total contribution to production. The $L^2 C^2$ term may be interpreted similarly with regard to the relationship between the numbers of Lieutenants and Captains.

Of course, no matter how reasonable the graphs or potential interpretations of the productive capacity function may appear, the paramount concern is that it

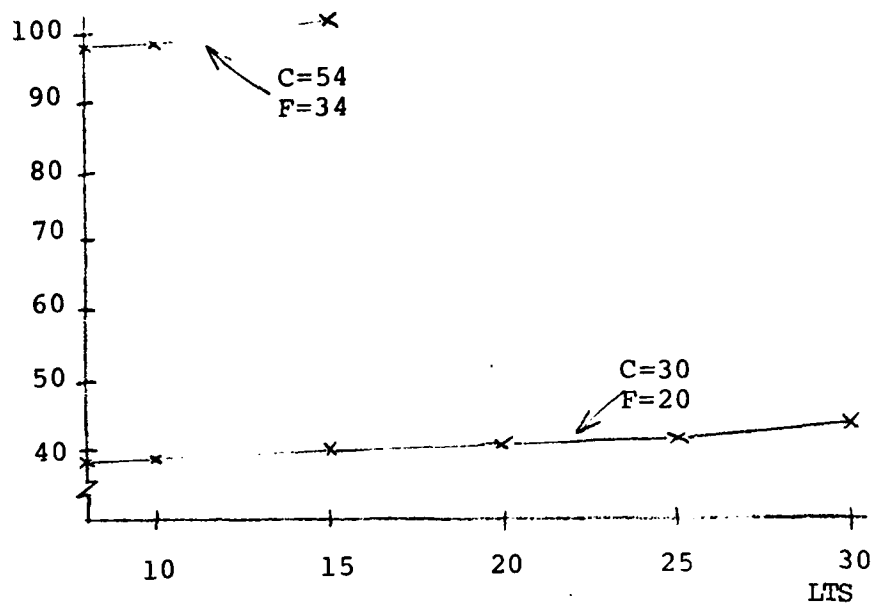


Fig. D-7. Productive Capacity of Lieutenants With Captains and Field Grade Officers Held Constant

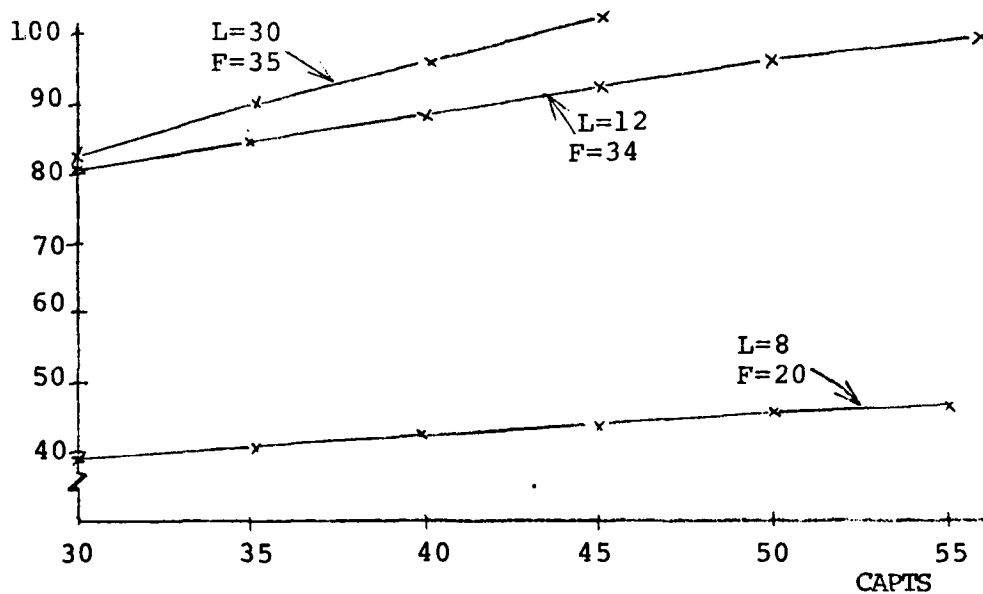


Fig. D-8. Productive Capacity of Captains With Lieutenants and Field Grade Officers Held Constant

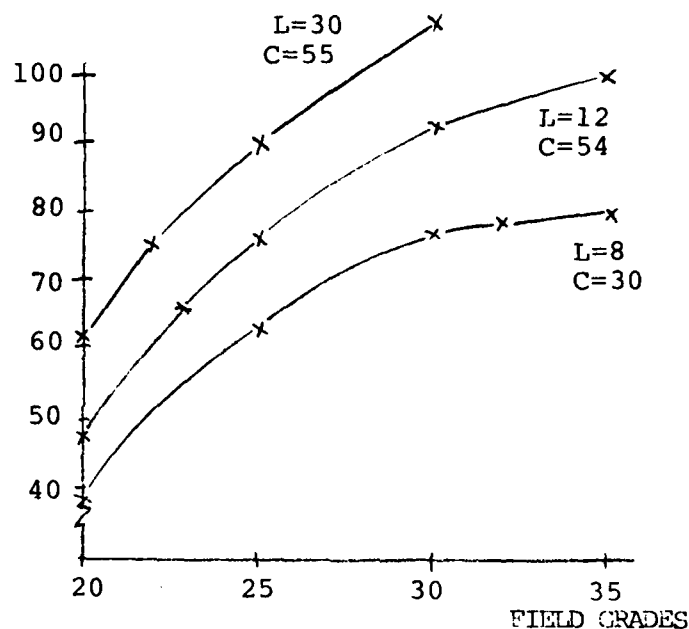


Fig. D-9. Productive Capacity of Field Grade Officers With Lieutenants and Captains Held Constant

perform its primary purpose; given two possible engineer officer force combinations, it must identify the one which the decision maker would expect to provide more productive capacity.

Test of the Model

To test how accurately the model reflects the decision maker's preference structure, the decision maker was asked to compare 14 different pairs of force combinations. His preferences were then compared to that indicated by the model. The results of this test are shown in Table D-VI. In all but three cases, the direction of preference indicated by the decision maker and the model

TABLE D-VI
SECOND ORDER POLYNOMIAL MODEL TEST RESULTS

FIRST FORCE COMBINATION					DECISION MAKER'S PREFERENCE	DIFFERENCE IN P VALUES	ALTERNATIVE FORCE COMBINATION					
LTS	CAPTS	FGS	TOTAL	P VALUE			P VALUE	LTS	CAPTS	FGS	TOTAL	
1.	12	54	34	100	99.8	>>	57.7	41.1	20	30	20	70
2.	14	53	30	99	94.6	>>	36.0	58.6	30	50	20	100
3.	20	30	30	80	78.7	>>	34.8	43.9	30	30	20	80
4.	14	53	30	97	93.4	>	11.1	82.3	20	30	35	85
5.	20	30	33	83	82.0	<	.6*	81.4	30	30	30	90
6.	14	40	30	84	84.8	<	-4.3	89.1	14	40	33	87
7.	20	30	35	85	82.3	<	-6.8	89.1	14	40	33	87
8.	10	53	33	96	97.3	>	10.5	86.8	20	40	30	90
9.	14	30	35	79	81.1	<	-7.1	88.2	10	40	33	83
10.	11	51	32	94	94.9	~	2.1*	92.8	10	55	30	95
11.	21	39	32	92	89.6	<	-4.3	93.9	10	50	32	92
12.	12	46	34	92	93.9	<	1.1*	92.8	30	38	32	100
13.	5	46	34	85	92.4	<	- .4	92.8	30	38	32	100
14	0	46	34	80	92.0	<	-3.7	95.7	35	38	34	105

* > - preferred to < less preferred than, ~ indifferent, >> strongly preferred to, << strongly less preferred than; * disagreement between the decision maker and model.

are the same. In all three of these cases which differ the decision maker did not express a strong preference and the difference between the productive capacity values was 2.1 or less. Whenever the difference in P values was greater than 3.6 the model and the decision maker indicated the same preference. Minor differences were anticipated since the mean square error of the model was 4.2.

Although these test results were encouraging, it should be noted that responses could vary depending upon how the questions are asked. This analysis devoted only cursory attention to such psychometric issues. The results could also vary depending upon who was asked. This research assumed that an experienced 28XX officer familiar with the job requirements of all grades was the best source. However, an argument could be advanced for interviewing actual job incumbents in the lower grades.

Summary and Conclusions

This investigation began by attempting to determine the appropriate form of a function to associate productive capacity with the numbers of Lieutenants, Captains, and Field Grade Officers in the development engineer officer force. Initial interviews with an experienced manager in an Air Force engineering organization revealed that this decision maker's preferences for officers in one grade category were not independent of the number of officers in the other categories. This eliminated two relatively

simple potential forms of the productive capacity function and indicated that the function must have some cross-product terms. Consequently, stepwise regression was used to estimate parameters of the model

$$P(L,C,F) = \sum_{i,j,k} \alpha_{ijk} L^i C^j F^k \quad i,j,k=0,1, \text{ or } 2$$

given scores elicited from the decision maker. The resulting model

$$P(L,C,F) = 12.9 + .031CF - .201F^2 + .0000006L^2C^2 - 153.5$$

appears to be a reliable representation of that decision maker's preference structure as elicited. Assuming that his preferences are indicative of the true productive capacity of development engineer officers throughout the Air Force, the function is an approximate indicator of the productive capacity of different development engineer officer forces resulting from alternative retention policies.

Vita

Kenneth L. Williams was born on 4 August 1949 in Atlanta, Georgia. He graduated from the Georgia Institute of Technology in 1971 with a Bachelor of Science Degree in Applied Mathematics. In February 1972, he went on active duty in the United States Air Force to serve as a computer systems financial branch chief and plans officer in Headquarters Aerospace Defense Command, Peterson Air Force Base, Colorado. In July 1976, he began his second Air Force assignment as the Data Automation Branch Chief at Bentwaters Royal Air Force Base, England. While at Bentwaters, he earned a Master of Science Degree in Management from Troy State University. Upon his return to the United States in 1979, Captain Williams entered the Air Force Institute of Technology as a graduate student in Operations Research.

He is married to the former Judith M. Johnson of Colorado Springs, Colorado. They have one eighteen-month-old daughter, Sarah Malinda.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/GOR/06/80D-7	2. GOVT ACCESSION NO. AD A094768	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A SYSTEM DYNAMICS MODEL FOR ASSESSING THE COST-EFFECTIVENESS OF USAF ENGINEERING OFFICER COMPENSATION POLICIES		5. TYPE OF REPORT & PERIOD COVERED M.S. Thesis
7. AUTHOR(s) Kenneth L. Williams Captain, USAF		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Institute of Technology (AFIT/EN) Wright-Patterson AFB, Ohio 45433		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
13. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE December 1980
		13. NUMBER OF PAGES 221
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES APPROVED FOR PUBLIC RELEASE; IAW AFR 190-17 <i>Laurel A. Lampela</i> LAUREL A. LAMPELA, 2d Lt, USAF Deputy Director, Public Affairs 06 JAN 1981		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) DEVELOPMENT ENGINEERING OFFICER, SYSTEM DYNAMICS, COST-EFFECTIVENESS, OFFICER PERSONNEL, RETENTION, COMPENSATION, BONUS, MILITARY PAY, ENGINEERING OFFICERS, MILITARY ENGINEERS, AIR FORCE QUALITY OF LIFE SURVEY, CAREER INTENT, SIMULATION		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This study formulates a methodology for evaluating alternative proposals to alleviate the Air Force's Development Engineering (28XX) officer shortage. Compensation was selected as the deci- sion variable from 18 factors related to engineering officer career intent. A compendium of pertinent studies reviewed was also provided. The 28XX officer responses to the most recent Air Force Quality of Life Survey indicate that salary has		

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substantial influence on career motivation. The value, or productive capacity of the 28XX officer force was assumed to be a function of the numbers of Lieutenants, Captains, and Field Grade Officers assigned. Data elicited from an experienced Development Engineering officer were fit to a second-order polynomial using stepwise regression to provide an approximate ordinal indicator of relative productive capacity. A System Dynamics model was constructed to provide force and cost projections based upon exogeneous inputs of the future demand for engineers and salary policies. The model's accession and retention rates respond positively to increases in the ratio of future expected military pay to future expected civilian pay. Uses of the model were illustrated, but more extensive validation and parameter estimation is required before the model can be used with confidence in formulating policies.

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